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Draft Bioventing Pilot Test Work Plan Addendum for

CAPEHART GAS STATION SITE (BUILDING 5635)

McClellan Air Force Base, California

Prepared for

Air Force Center for Environmental Excellence

Brooks AFB, Texas and
McClellan Air Force Base, California

January 1994

Prepared by

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Draft Bioventing Pilot Test Work Plan Addendum for

CAPEHART GAS STATION SITE
(BUILDING 5635)
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DRAFT BIOVENTING PILOT TEST WORK PLAN ADDENDUM
FOR
CAPEHART GAS STATION SITE (BUILDING 5635)
McClellan Air Force Base, California

1.0 INTRODUCTION

This Draft Addendum modifies the existing "Draft Bioventing Pilot Test Work Plan for Tank Farm #2, Tank Farm #4, SA 6, PRL T-46, Building 720 at McClellan Air Force Base, and Davis Global Communications Site, Davis, California" (ES, 1993) and provides site-specific information for additional in situ bioventing pilot testing activities to be performed at the Capehart Gas Station Site, Building 5635, McClellan Air Force Base, California (McClellan AFB).

Much of the background information on the Capehart Gas Station Site used in this Draft Addendum is derived from prior studies and reports which are listed in Section 8.0. This information includes site maps, site histories, site geology, and sampling and analytical data.

1.1 BIOVENTING PILOT TEST ORGANIZATION

The bioventing pilot test which will be conducted at the Capehart Gas Station Site has three primary objectives: 1) to assess the potential for supplying oxygen throughout the fuel hydrocarbon-contaminated soil zone; 2) to determine the rate at which indigenous microorganisms will degrade the fuel in the soil when stimulated by oxygen-rich soil gas; and, 3) to evaluate the potential for sustaining these rates of fuel biodegradation until the contamination is remediated below regulatory standards.

The bioventing pilot test will be divided into two test events. An initial pilot test will determine the technical feasibility and fuel biodegradation rates. Important design parameters such as radius of venting influence and air permeability have in part been determined by a previous soil vapor extraction (SVE) pilot test (CH2M Hill, 1992). An extended (one-year) pilot test will determine the longer-term application of bioventing technology, including an assessment of air emissions treatment.

If bioventing proves to be applicable, pilot test data could be used to design and implement a bioventing remediation system. A significant amount of the fuel contamination should be biodegraded during the extended (one-year) pilot test since the bioventing will take place within the area of highest known soil-vapor contamination.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled "Test Plan and Technical Protocol for a Field Treatability Test for Bioventing" (Hinchee et al., 1992). This protocol document will also serve as the primary reference for detailed procedures which will be used during pilot testing.

2.0 SITE DESCRIPTION

The following section provides a brief summary of the location, history, geology, and known contaminant distribution at the Capehart Gas Station Site.

2.1 Site Location and Description

The Capehart Gas Station is located in the Capehart Housing Area of McClellan AFB at the northeast corner of Navajo Drive and Aztec Way in North Highlands, California. Figure 2.1 is a site location map.

The site, shown in Figure 2.2, currently consists of a main store and office building, a four-pump gasoline island with an overhead canopy, and three 10,000-gallon capacity underground storage tanks (USTs) containing various grades of unleaded gasoline. The ground surface is entirely paved, mostly with asphalt except for concrete areas around the store/office building, underneath the canopy around the pump island, and above the UST complex. Asphalt patching exists over the supply and return pipelines between the USTs and the pump island, around the UST area, over the tank vent lines, and over the electrical and air lines. The ground surface is relatively flat with a downward slope to the south of a two percent grade. The gas station is bounded on the west and south by Aztec Way and Navajo Drive, respectively, on the north by a fence separating it from a contractor's yard, and to the east by the shoppette building and parking lot.

2.2 Site History

The following is a listing of events related to environmental investigations at the site:

- Early 1987 - Apparent release of 2,000 gallons of unleaded gasoline.
- March 1987 - Backhoe exploration (by Radian Corporation) of underground fuel piping area and soil sampling.
- 31 Mar to 02 Apr 1987 - Soil-gas survey of site by Western Geo-Engineers.
- 1987 - Subsurface exploration (by an unknown contractor) including the drilling of seven soil borings and installation of seven soil vapor monitoring wells (SVMWs).
- January 1992 - Subsurface exploration (by CH2M Hill) including the drilling of six soil borings, subsurface soil sampling and laboratory analysis, installation of five SVMWs, abandonment of three existing SVMWs (previously installed in 1987), abandonment of one soil boring, soil-vapor sampling and laboratory analysis, and performance of an air permeability (AP) test.
- November 1992 - Excavation and replacement of USTs and fuel lines.
- June 1993 - Soil-vapor sampling (by CH2M Hill) from seven SVMWs and laboratory analysis.

2.2.1 Gasoline Release and Backhoe Exploration

During early 1987, an apparent release of approximately 2,000 gallons of unleaded gasoline was detected as a result of the station's inventory reconciliation program. During the second week of March 1987, a shallow exploration program by Radian

FIGURE 2.1

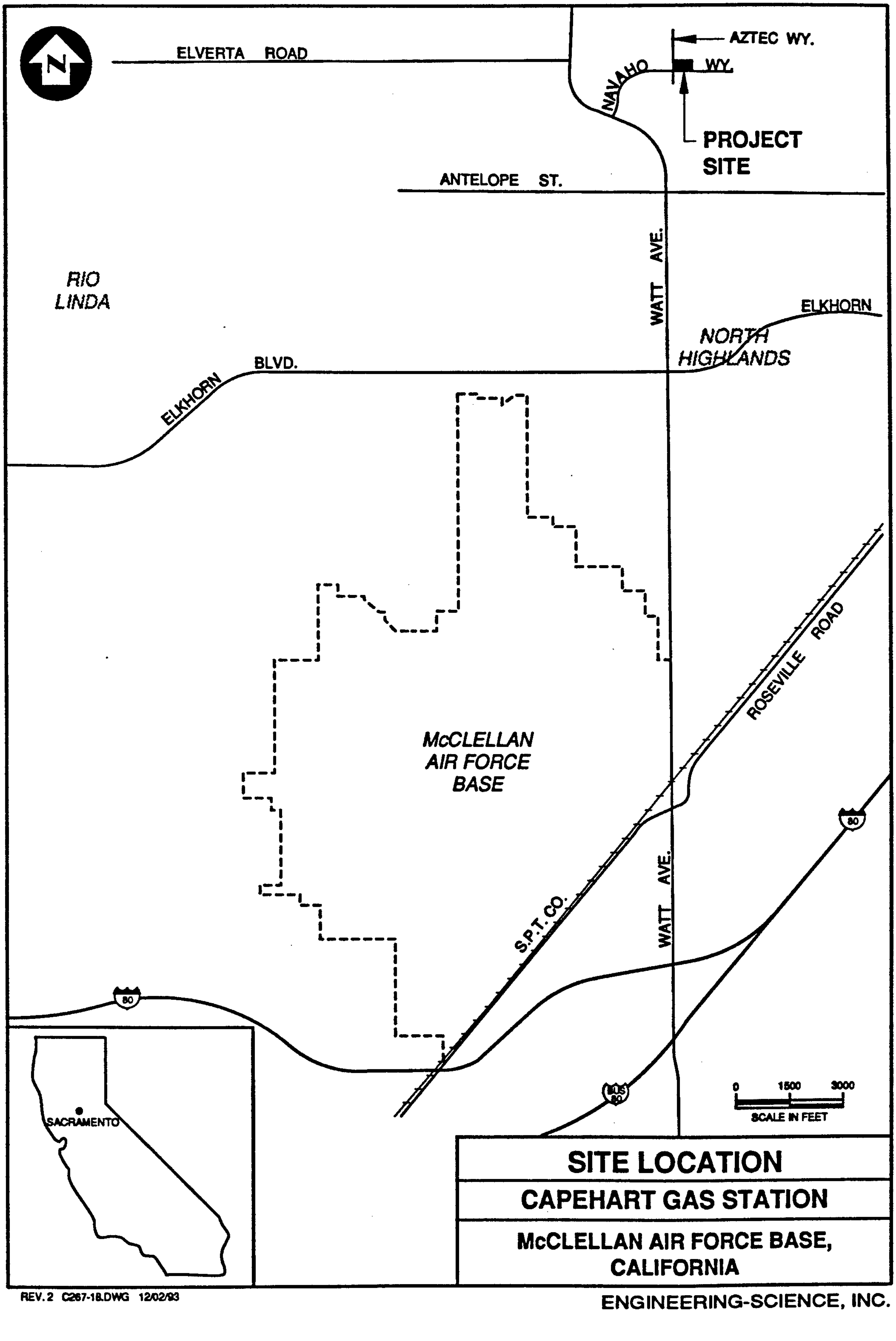

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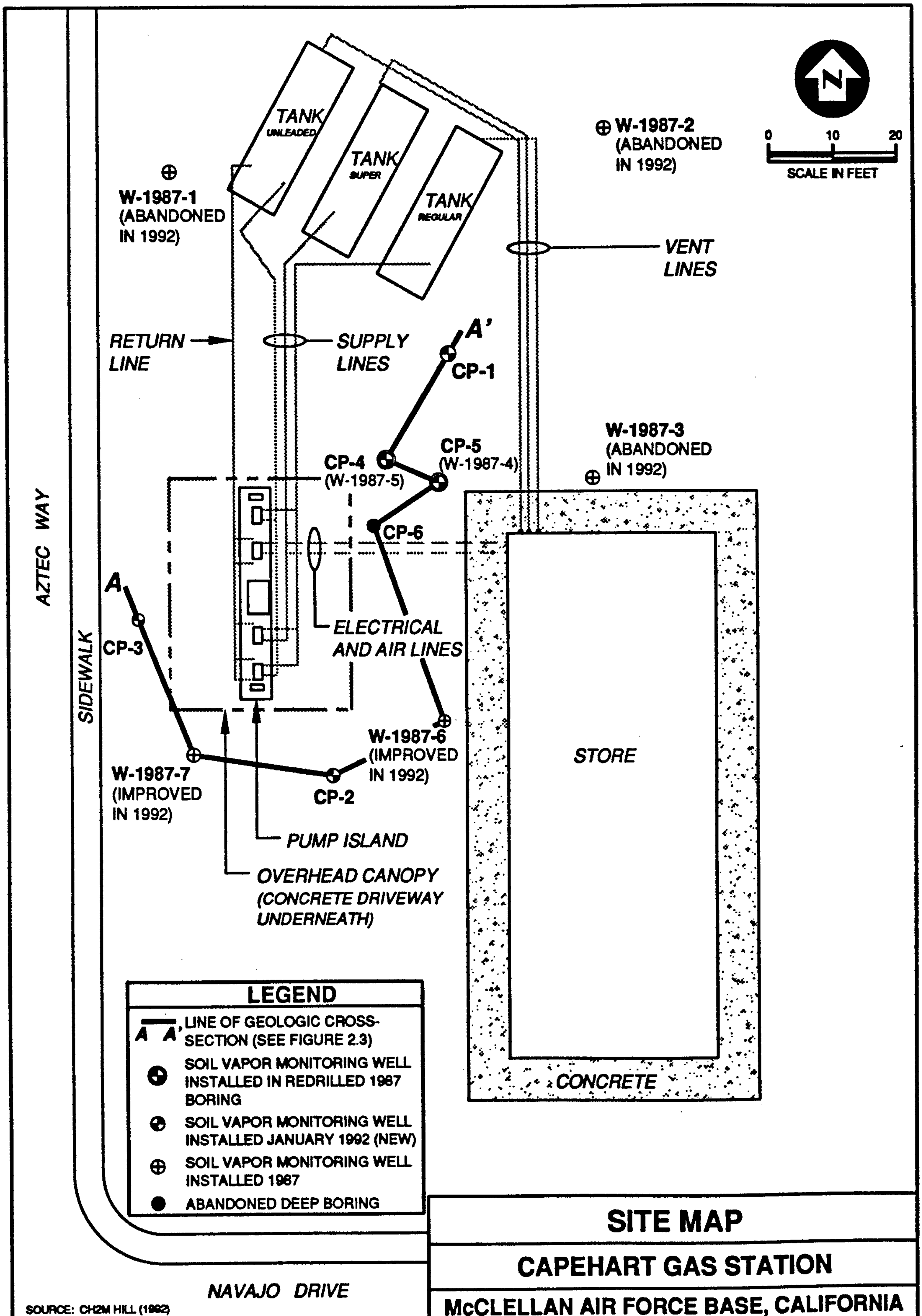
FIGURE 2.2



SITE MAP

CAPEHART GAS STATION

McCLELLAN AIR FORCE BASE, CALIFORNIA

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Corporation using a backhoe uncovered a break in the fuel pipe between the unleaded gasoline UST and the pump island. Soil samples were collected underneath the break in the pipe at depths of 4 feet, 5.5 feet, and 7.5 feet below ground surface (bgs).

These samples were analyzed by Eureka Laboratories, Inc. for total petroleum hydrocarbons (TPH) using EPA Method 8015 Modified, Aromatic Volatile Organics using EPA Method 8020, and metals using EPA Method 6010. Detected concentrations of TPH as gasoline (TPH-g) ranged from 140 milligrams per kilogram (mg/kg) at 4 feet bgs to 42 mg/kg at 5.5 feet bgs. Concentrations of TPH as diesel (TPH-d) and as motor oil (TPH-mo) were not detected. Detected concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) ranged from 4.7, 18.1, 9.1, and 59.3 mg/kg, respectively, at 4 feet bgs to 0.17, 1.5, 0.34, and 4.0 mg/kg, respectively, at 5.5 feet bgs.

2.2.2 Soil-Gas Survey

Western Geo-Engineers (WEGE) conducted a soil-gas survey at the site from 31 March to 02 April 1987 (WEGE, 1987). The survey included advancement of 25 test holes to depths ranging from 6 feet to 21.9 feet bgs. Soil-gas samples were collected from a minimum of one depth to a maximum of four depths in each test hole. The sampled depths were 4 feet, 6 feet, 8 feet, 12 feet, 16 feet, and 20 feet bgs. A total of 54 soil-gas samples were collected. Subsurface gasoline vapor readings in soil gas were detected up to 15,550 parts per million by volume (ppmv) from Test Hole Number 7 at 16 feet bgs, located approximately 25 feet northeast of the pump island's north end (near Well CP-4 shown on Figure 2.2). A table of gasoline vapor readings in soil gas, and isoconcentration contour maps of these gasoline vapor readings, are included in Appendix A.

Gasoline (free product) was obtained from Test Hole Number 13 (0.3 foot thickness of free product with no water recovery) from approximately 18.3 feet bgs. Test Hole Number 13 was also near the current location of CP-4 (Figure 2.2).

2.2.3 1987 Subsurface Exploration

Sometime after the evaluation of the soil-gas survey data, an additional subsurface exploration program was performed in 1987 by an unknown contractor. A total of seven soil borings were advanced at locations indicated on Figure 2.2 (W-1987-1 through W-1987-7). SVMWs were installed in each of these seven soil borings. All SVMWs were reportedly constructed of 2-inch diameter Schedule 40 polyvinyl chloride (PVC) casing. In some of the wells, there was no evidence found of grout or bentonite seals during a later investigation, and the screened intervals appeared to have been originally backfilled with native materials. Screened interval lengths were reported to range from 5.3 feet (W-1987-4) to 34.4 feet (W-1987-2), with the deepest screen base at 35.0 feet bgs (W-1987-7). Information including boring logs and laboratory analytical results are not available.

2.2.4 1992 Subsurface Exploration

An additional subsurface exploration program was conducted in January 1992 (CH2M Hill, 1992). Prior to field operations, the SVMWs installed in 1987 were evaluated for inclusion into or exclusion from this exploration program based on well location, depth,

screened interval, and quality of bentonite-grout surface seals. Wells W-1987-1, W-1987-2, and W-1987-3 were abandoned because they were deemed unusable for the purposes of the 1992 investigation due to uncertainty of the condition of the well casings and well completions. Wells W-1987-6 and W-1987-7 were selected for incorporation into the 1992 investigation because they were located in areas near the contamination source area and screened over desirable intervals for soil-gas monitoring. Wells W-1987-4 and W-1987-5 were redrilled and new wells installed because these 1987 wells were deemed unacceptable due to lack of adequate bentonite-grout surface seals and the shallow depth to the top of the well screen in W-1987-5 (approximately 0.5 feet bgs).

In addition to the redrilling of W-1987-4 and W-1987-5, four soil borings were advanced to depths ranging from approximately 21 feet to 108 feet bgs. Locations were selected based on the 1987 soil-gas survey data, the location of the 1987 wells not abandoned, and other factors such as overhead obstructions, pipe and utility trench locations, and AP test monitoring requirements. Subsurface soil samples were collected from each of the four new borings, generally at five-foot intervals, and one sample per boring was collected in the two borings used for replacement wells.

SVMWs were installed in five of the six borings (CP-1, CP-2, CP-3, CP-4, and CP-5) using Schedule 40 PVC casing and screens with filter pack intervals and annular seals. One boring (CP-6) was abandoned by backfilling with grout to avoid creating a contaminant pathway to the groundwater table, since this was the only boring drilled to a depth near groundwater.

Following completion of the well installations, soil-gas samples were collected from CP-1, CP-2, CP-3, CP-5, W-1987-6, and W-1987-7. Additional soil-gas samples were collected from CP-4 at the beginning and at the end of the AP test. Prior to sampling, the wells were purged of at least 20 well volumes of air with a vacuum pump at a minimum flow rate of 50 liters per minute (L/min). After purging, a soil-gas grab sample was collected from each well with a 6-liter Summa® cannister connected to the well-head and allowed to fill for 15.25 minutes at a rate of approximately 262 milliliters per minute (ml/min).

An AP test was conducted on 11 January 1992 using CP-4 as an air extraction well and CP-1, CP-2, and CP-5 as pressure monitoring wells. Results of this test are discussed in Section 3.6.

Chemical analyses were performed on soil samples for TPH-g (Method SW 8015 Modified) and BTEX (Method SW 8020). Some soil samples were tested for physical parameters and nutrients including Total Organic Carbon content (EPA Method 415.1), pH (Method SW 9045), moisture content (ASTM Method D2216), grain size distribution (ASTM Method D422), available ammonia (EPA Method CE81), available phosphorous (USBR Method 514.8), and available nitrate (EPA Method 300.0). Analytical results are presented and discussed in Section 2.4.

Chemical analyses were performed on soil-gas samples for TPH-g and BTEX (Modified EPA Method TO-14). Analytical results are also presented and discussed in Section 2.4.

2.2.5 Excavation and Replacement of USTs

In November 1992, the three USTs, the fuel supply and return lines, and the tank vent lines were removed and replaced at the site.

2.2.6 1993 Soil-Gas Sampling

In June 1993, soil-gas samples were collected (CH2M Hill, 1993a) from CP-1, CP-2, CP-3, CP-4, CP-5, W-1987-6, and W-1987-7 (the same wells that were sampled in January 1992). Samples were collected from each well in a 850-ml Summa® cannister. Information regarding the sampling methodology was not available for comparison to the January 1992 soil-gas sampling event.

Chemical analyses were performed on soil-gas samples for BTEX (EPA Method TO-14) and TPH-g (Modified EPA Method TO-14). Analytical results from this event are also presented and discussed in Section 2.4.

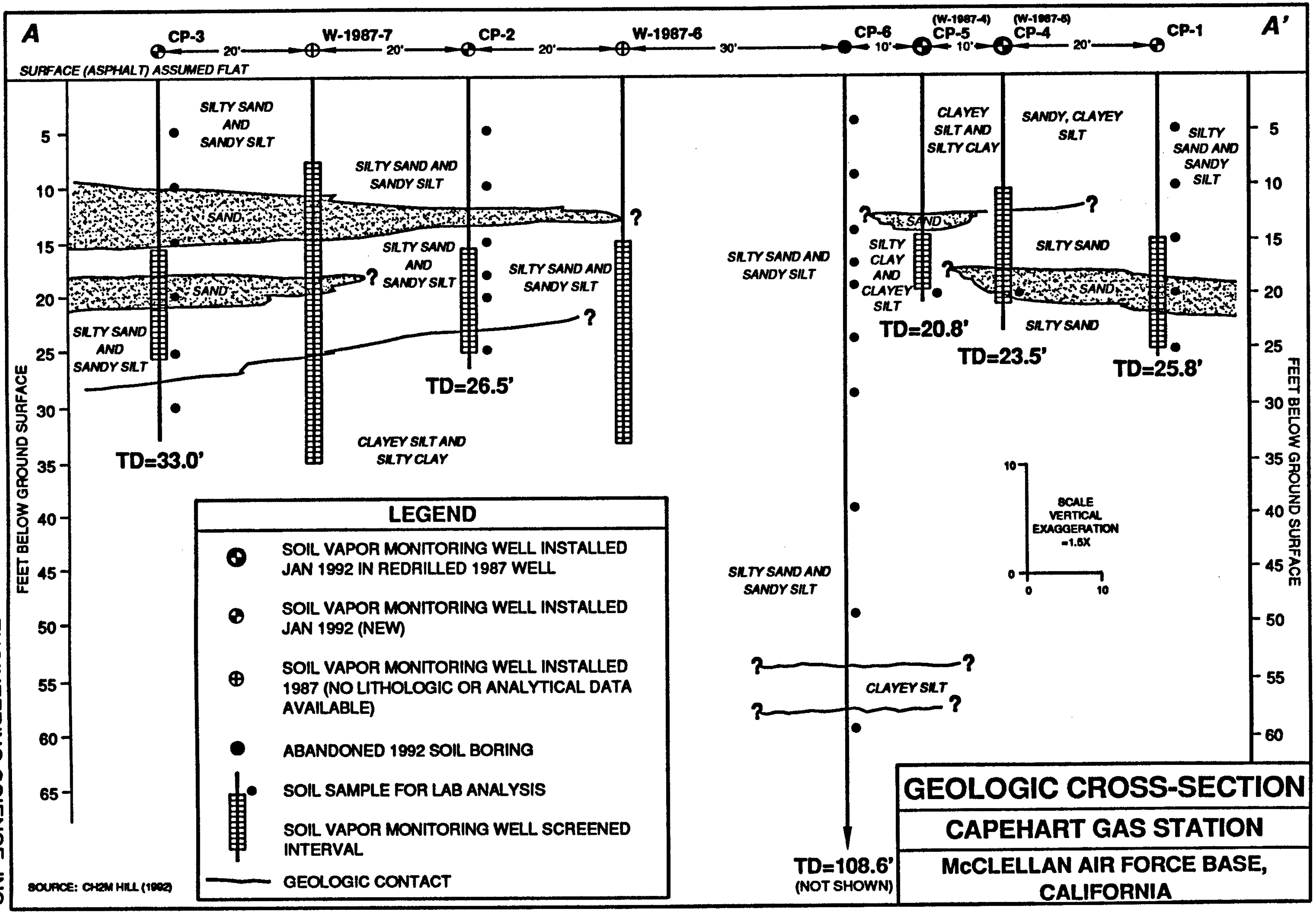
2.3 Site Geology

Figure 2.3 is a geologic cross-section constructed from field boring logs and well construction information from CP-1, CP-2, CP-3, CP-4, and CP-5, and from the abandoned boring CP-6. Wells W-1987-6 and W-1987-7 are also shown, but the lithologic interpretation is not based on these wells since no boring logs are available. This cross-section has a variable orientation (see Figure 2.2) which allows an interpretative view of the subsurface soil profile around the pump island from ground surface to approximately 30 feet bgs, with additional information from boring CP-6 down to 65 feet bgs. Also shown are the screened intervals in the SVMWs and the locations from which soil samples were submitted for laboratory analysis. The lithologic interpretation shown on the cross-section is generalized, and lateral correlation from boring to boring is only possible for the more prominent sand zones, since the nature of the finer-grained intervals is highly variable.

Based on the six soil borings, the soil profile consists of highly stratified, discontinuous layers of silt, sandy silts, silty sands, and sands. The fine-grained silt and sandy silt layers in the upper 50 feet of the soil profile are generally stiff to very hard and of low to moderate plasticity. The sand and silty sand layers within this interval are generally dense and consist of well sorted, fine to medium-grained micaceous sand. Individual layers were described to be relatively thin (1 to 2 feet thick). Based on the CP-6 borehole information, soils below 50 feet bgs are generally composed of interbedded silts and sands which generally become less hard and increase in clay content with increasing depth. Soil boring logs for the six borings are included in Appendix B.

Evaluation of the hydrogeology of the site is not possible since there are no groundwater monitoring wells, and none of the borings previously discussed reached groundwater. Soil conditions were described as moist in places, but never wet or saturated. At the time of the January 1992 investigation, groundwater was estimated to occur at approximately 100 feet bgs based on regional groundwater data. Boring CP-6 was advanced to approximately 108 feet bgs but did not encounter groundwater. Regionally, horizontal groundwater movement in the uppermost saturated zone is

FIGURE 2.3



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generally in a south-southwest direction toward a regional pumping cone of depression south of Sacramento. However, groundwater flow directions at McClellan AFB are variable and are in part dependent on location.

2.4 Previous Soil and Soil-Gas Analytical Results

Results of limited soil sampling during the March 1987 backhoe exploration event were previously given in Section 2.2.1. Results of the 1987 soil-gas survey by WEGE were previously discussed in Section 2.2.2 and given in Appendix A. Information on any laboratory results of sampling that may have been performed during the subsequent 1987 subsurface exploration are not available. Therefore, analytical results given below are for the soil samples collected in 1992 and for the soil-gas samples collected in 1992 and 1993 and are presented in Tables 2.1 and 2.2. The vertical locations of soil samples and the screened intervals from which the soil-gas samples were collected are shown on the geologic cross-section (Figure 2.3).

2.4.1 Soil Analytical Results

TPH-g was detected above laboratory reporting limits in four samples at depths of 14 feet, 19 feet, 20 feet, and 25 feet bgs. Detected concentrations ranged from 1.2 to 32 mg/kg. Three of the four detections were at concentrations less than 2 mg/kg.

At least one of the four BTEX constituents were detected above laboratory reporting limits in 10 soil samples at depths ranging from 5 feet to 49 feet bgs. Detected benzene concentrations ranged from 0.009 to 0.190 mg/kg. Detected toluene concentrations ranged from 0.005 to 0.370 mg/kg. Detected ethylbenzene concentrations ranged from 0.006 to 0.092 mg/kg. Detected total xylene concentrations ranged from 0.023 to 1.1 mg/kg.

Six soil samples collected from depths between 15 feet and 25 feet bgs were analyzed for Total Organic Carbon (TOC) content and pH levels. Detected concentrations of TOC ranged from 170 to 1,060 mg/kg. Five of the six TOC concentrations were less than 600 mg/kg. Soil pH levels ranged from 7.09 to 8.23.

Five of the six soil samples just discussed were also analyzed for available nutrients by testing for ammonia, phosphorous, and nitrate. Ammonia was not detected above reporting limits in any of the samples. Phosphorous was detected in each sample at concentrations ranging from 2.60 to 4.63 mg/kg. Nitrate was detected above reporting limits in only one sample at a concentration of 0.788 mg/kg. The significance of these nutrient levels is discussed in Section 3.0.

Moisture content was determined for 11 soil samples collected from depths between 14 feet and 29 feet bgs. Soil moisture contents ranged from 6.4 percent by weight (in sand) to 25.5 percent by weight (in sandy silt).

Five sandy soil samples were field selected for grain size analysis. Based on the laboratory analysis, all of the selected soils were classified as poorly graded (well sorted), fine-grained sand with approximately 6 to 12 percent fines. Based on the hydrometer portion of the analyses, the fines are primarily silt.

Table 2.1
Soil Analytical Results for
Capehart Gas Station
McClellan AFB, California

		Purgeable Petroleum HC	Volatile Aromatic Hydrocarbons			
	Method:	SW8015 modified	SW8020			
	Analyte:	TPH-g	Benzene	Toluene	Ethylbenzene	Total Xylenes
	Units:	all concentrations in mg/kg				
Location	Depth (ft bgs)					
CP-1	5					
	10					
	15					
	20					
	25					
CP-2	5					
	10					
	15					
	20					
	20 (dup)					
	25					
CP-3	5					
	10					
	15					
	20	1.3	0.11	0.11	0.11	0.09
	25	1.2	0.19	0.021	0.013	0.088
	30		0.009			
CP-4	20					
CP-5	20			0.005		
CP-6	4					
	9					
	14	32	0.032	0.37	0.092	1.1
	19	1.2	0.020	0.035		0.027
	19 (dup)					
	24			0.005		
	29			0.006		
	39.5		0.010	0.006		
	49		0.096	0.034	0.006	0.023
	59.5					
	70					
	79					
	90					
	100					
	105					
	105 (dup)			0.005		

LEGEND

bgs : below ground surface

TPH-g : Total Petroleum Hydrocarbons as gasoline

(dup) : duplicate

[shaded] : not detected

chtab21

SOURCE: CH2M Hill, 1992

12/02/93

Table 2.1 (continued)
Soil Analytical Results for
Capehart Gas Station
McClellan AFB, California

Location	Analyte:	Moisture Content	pH	Total Organic Carbon	Ammonia as Nitrogen	Nitrate as Nitrogen	Phosporus	Sand	Silt	Clay
	Method:	ASTM D2216	SW9045	EPA 415.1	EPA CE 81	EPA 300	USBR 514.8	ASTM D2216		
	Units:	(%)	(units)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(%)	(%)	(%)
Location	Depth (ft bgs)									
CP-1	20	11.4	8.23	1,060	NA	NA	NA	90.8	8.2	1.0
CP-2	15	10.7	7.37	260		0.788	3.41	NA	NA	NA
	18	6.4	NA	NA	NA	NA	NA	93.4	5.1	1.5
	25	23.9	7.09	340			4.63	NA	NA	NA
CP-3	15	23.5	7.07	580			4.36	NA	NA	NA
	20	11.5	7.95	170			2.60	86.8	10.7	2.5
CP-4	20	8.0	NA	NA	NA	NA	NA	91.8	6.2	2.0
CP-6	14	21.6	NA	NA	NA	NA	NA	NA	NA	NA
	17	9.9	NA	NA	NA	NA	NA	89.2	9.8	1.0
	24	17.4	7.45	250			3.41	NA	NA	NA
	29	25.5	NA	NA	NA	NA	NA	NA	NA	NA

LEGEND

bgs : below ground surface
TPH-g : Total Petroleum Hydrocarbons as gasoline
(dup) : duplicate

[shaded] : not detected
NA : not analyzed

SOURCE: CH2M Hill, 1992

chlab21c
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Table 2.2
Soil Gas Analytical Results for
Capehart Gas Station
McClellan AFB, California

Date:	January 1992					June 1993				
Analyte:	TPH-g	Benzene	Toluene	Ethylbenzene	Total Xylenes	TPH-g	Benzene	Toluene	Ethylbenzene	Total Xylenes
Method:	EPA TO-14 modified					EPA TO-14 modified				
Units:	all concentrations in ppmv									
Location										
CP-1	3,600	34	20	1.7	13	0.899	0.0429	0.106	0.00932	0.02767
CP-2	310	0.34					0.0193	0.248	0.00331	0.02405
CP-3	7,200	170	11	7.4	29	146	366	8.32	32.9	59.12
CP-3 (dup)	n.a.	n.a.	n.a.	n.a.	n.a.	207	414	10.8	65.3	126.86
CP-4	2,900	17	5.9			961	3750	3850	651	4360
CP-4[1]	8,100	160	27			n.a.	n.a.	n.a.	n.a.	n.a.
CP-5	1,100	5.8	1.9	0.66	2.6	10.5	1.79	0.251	0.0702	0.783
W-1987-6	540	1.6	0.097		0.096		0.133	0.0738	0.0679	0.2251
W-1987-7	480	0.27				2.13	1.12	1.37	0.132	1.005
W-1987-7 (dup)	420	0.23				n.a.	n.a.	n.a.	n.a.	n.a.

LEGEND

bgs : below ground surface
TPH-g : Total Petroleum Hydrocarbons as gasoline
[1] : after 1 hour of air extraction at 20 scfm

(dup) : duplicate
n.a. : not applicable
(shaded) : not detected

SOURCE: CH2M Hill (1992, 1993)

chtab22
11/24/93

2.4.2 Soil-Gas Analytical Results

TPH-g and benzene were detected in each of the eight soil-gas samples collected in January 1992. Each well was sampled prior to the AP test (with the possible exception of CP-4 which was sampled at the beginning of the AP test as previously discussed in Section 2.2.4), and CP-4 (the air extraction well) was sampled again at the end of the AP test. TPH-g concentrations ranged from 310 to 8,100 ppmv. Benzene concentrations ranged from 0.23 to 170 ppmv. Toluene, ethylbenzene, and total xylenes were also detected in some of the samples with detected concentration ranges of 0.097 to 27 ppmv toluene, 0.66 to 7.4 ppmv ethylbenzene, and 0.096 to 29 ppmv total xylenes.

The maximum concentration of TPH-g was collected from CP-4 at the end of the AP test, which lasted approximately one hour. The TPH-g concentration increased from 2,900 ppmv prior to the test to 8,100 ppmv at the conclusion of the test. Similarly, benzene levels in CP-4 increased from 17 to 160 ppmv and toluene concentrations increased from 5.9 to 27 ppmv. Neither ethylbenzene nor xylenes were detected in CP-4. Increases in soil-gas concentrations of TPH-g and BTEX during AP testing are typical during very early air extraction, although concentrations tend to decrease with extended air extraction as the initial pore volume of soil gas is removed.

TPH-g was detected in five of the seven soil-gas samples collected in June 1993, with detected concentrations ranging from 0.899 to 961 ppmv. All BTEX components were detected in all of the seven samples collected with concentration ranges of 0.0193 to 3,750 ppmv benzene, 0.0738 to 3,850 ppmv toluene, 0.0033 to 651 ppmv ethylbenzene, and 0.02405 to 4,330 ppmv total xylenes. The maximum concentrations of TPH-g and BTEX were found at CP-4.

Benzene concentrations in soil-gas samples increased in CP-3, CP-4, and W-1987-7 from the January 1992 sampling event to the June 1993 event. However, the TPH-g concentrations have decreased in all the wells between the two sampling events. Reasons for these temporal changes in soil-gas concentrations are unknown, but may be due in part to the following considerations.

The June 1993 soil-gas analytical results for TPH-g are difficult to reconcile with the results for BTEX since for six of the eight samples, the sum of the BTEX values exceeded the reported TPH-g value. The reported 1993 TPH-g values may not be truly representative because of the analytical method used (CH2M Hill, 1993b). For these TPH-g analyses, the complete retention times of the whole chromatogram were compared to the relative response factor of toluene. Therefore, the results are not "true TPH-g" values, and this may explain why the 1993 TPH-g values are significantly lower than the 1992 results. In addition, analyses of the soil-gas samples from the two sampling events were performed by different laboratories. Also, it is unclear if similar sampling protocols (e.g., well purge times and sample collection times) were used for the two soil-gas sampling events in 1992 and 1993, which may account for differing results.

2.5 Distribution of Contamination

Soil sample analytical data indicate that low-level soil contamination exists 14 to 25 feet bgs in the vicinities of CP-3, CP-5, and CP-6. Contaminants were not detected in

CP-1, CP-2, or CP-4. Based on the single deep boring (CP-6), the contamination does not appear to extend vertically below approximately 50 feet bgs. Field description of soil samples during the 1992 investigation noted fuel odors between approximately 8 feet and 25 feet bgs in CP-1, CP-3, CP-4, CP-5, and CP-6 (variable depths in each well). No odors were noted in CP-2. Some slight soil discoloration indicative of fuel contamination was noted in CP-1, CP-5, and CP-6, but was relatively rare. No such discoloration was noted in CP-2, CP-3, or CP-4. During the 1987 soil-gas investigation, free gasoline product was encountered at approximately 18.3 feet bgs. Although gasoline odors were noted in the boreholes noted above, no evidence of free gasoline or gasoline-saturated soils was observed during the 1992 investigation.

Soil-gas analytical results indicate that elevated levels of gasoline contamination are present in the vapor phase in each of the seven SVMWs sampled in 1992 and 1993. The results imply that there may be areas of soil contamination with higher concentrations of TPH-g/BTEX than indicated by the soil-sample analyses. Soil-gas samples were not collected below approximately 30 feet bgs. Based on comparable soil matrix contaminant concentrations, it is possible that elevated soil-gas concentrations may exist below 30 feet. Among the equilibrium vapor samples (collected after well purging but before extensive air extraction) collected in 1992, the highest concentrations of TPH-g and benzene were found in CP-3 located west of the pump island. However, results of the soil-gas survey in 1987 indicated the highest concentrations of contaminant vapors were located in three areas: near CP-4; near the unleaded gasoline UST; and just west of the return line between the pump island and the unleaded gasoline UST (see Appendix A).

3.0 SITE-SPECIFIC ACTIVITIES

The purpose of this section is to describe the work that will be performed by Engineering-Science, Inc. (ES) at the Capehart Gas Station Site. Activities to be performed include drilling of one additional soil vapor monitoring well (SVMW), an abbreviated initial bioventing pilot test, and an extended (one-year) bioventing pilot test. Additional soil sampling, downhole soil-gas sampling, and well construction activities will be limited to one additional boring and well completion. Wells installed for previous site investigations (CH2M Hill, 1992) will also be utilized for bioventing pilot testing, and previously collected soil and soil-gas sample analytical data will be used to aid the interpretation of pilot test results. Because of the significant variation in soil-gas analytical results between the January 1992 and June 1993 sampling events, additional soil-gas sampling from existing wells will also be performed to evaluate current site conditions. The initial pilot test will not include an AP test since one was previously conducted (CH2M Hill, 1992).

The abbreviated initial pilot test will include an *in situ* respiration (ISR) test, procedures for which are discussed in more detail in Section 3.7. The extended (one-year) pilot test will include treatment of extracted soil vapors, system monitoring, additional ISR tests, and confirmatory soil and soil-gas sampling. The proposed SVE system and injection blower system configurations are also discussed in this section.

No dewatering or groundwater treatment will take place during the pilot testing. Pilot test activities will be confined to remediation of unsaturated soils that can be aerated and monitored with the existing well network plus the one additional well.

Existing soil sample analytical data show the subsurface soil profile to contain sufficient moisture to sustain respiration and biodegradation for the duration of the pilot test. Although the soil analytical data for available ammonia and nitrate indicated very low levels of these inorganic nutrients, previous research has indicated that nutrient recycling of organic nitrogen or nitrogen fixation by nitrogenous bacteria may supply basic nutrient needs. Nutrient addition has been shown to be only marginally effective at similar petroleum contaminated sites.

3.1 Location of Existing Soil Vapor Monitoring Wells

Well CP-4 will be used as a primary vapor extraction well (VEW) during the extended (one-year) pilot test. This well is located approximately 20 feet northwest of the station building (Figure 2.2). CP-4 was chosen as the primary VEW because it is located within the area of highest-detected concentrations of TPH-g and BTEX in previously-collected soil-gas samples (Appendix A), and it is a 4-inch diameter well of sufficient screen length and construction.

Wells CP-1, CP-2, CP-3, CP-5, W-1987-6, and W-1987-7 will be used as vapor monitoring points (VMPs) during the initial and long-term (one-year) pilot tests. All of these wells are located within the 70-foot radius of influence documented during the previous AP test.

For purposes of monitoring background soil-gas conditions, the background VMP installed by ES at the Base Fire Department (Building 737) in July 1993 will be used. Oxygen levels in soil-gas at this VMP were approximately 18%. Since the soil analytical results at the Capehart Gas Station Site indicate low TOC levels, there is little indication that inorganic or natural carbon sources would significantly contribute to observed oxygen utilization during an ISR test.

3.2 Construction of Existing Soil Vapor Monitoring Wells

Construction details of CP-4 are shown in Figure 3.1. This well was constructed of 4-inch internal diameter (ID), flush-threaded Schedule 40 PVC casing, with an interval of 0.01-inch slotted screen between 10.8 feet and 20.8 feet bgs (10-foot) screened length. A slip cap was placed on the bottom of the screen, and a screw cap was placed at the surface end of the blank casing. Stainless-steel centralizers were placed at the top and bottom of the well screen to center the screen in the borehole. Lone star No. 6 sand was used for the filter pack to backfill the borehole/screen annulus to within approximately 2 feet above the top of the well screen. A 1.5-foot thick bentonite seal was emplaced on top of the filter pack with hydrated bentonite pellets, and the surface seal (bentonite-cement grout) was emplaced from the bentonite seal to near the surface. The well was completed at the surface in a 12-inch diameter steel Christy box with bolt-down traffic lids. The Christy box was completed slightly above the surrounding asphalt surface to provide drainage away from the surface vault.

Construction details of CP-1, CP-2, CP-3, and CP-5 are also shown in Figure 3.1. These wells were constructed of 2-inch ID Schedule 40 PVC casing, with intervals of 0.01-inch slotted screen as listed in Figure 3.1. The screened interval lengths ranged from approximately 5 feet (CP-5) to 10 feet (CP-1, CP-2, and CP-3) with the top of the screen no shallower than about 15 feet bgs. All other construction details are approximately the same as those for CP-4.

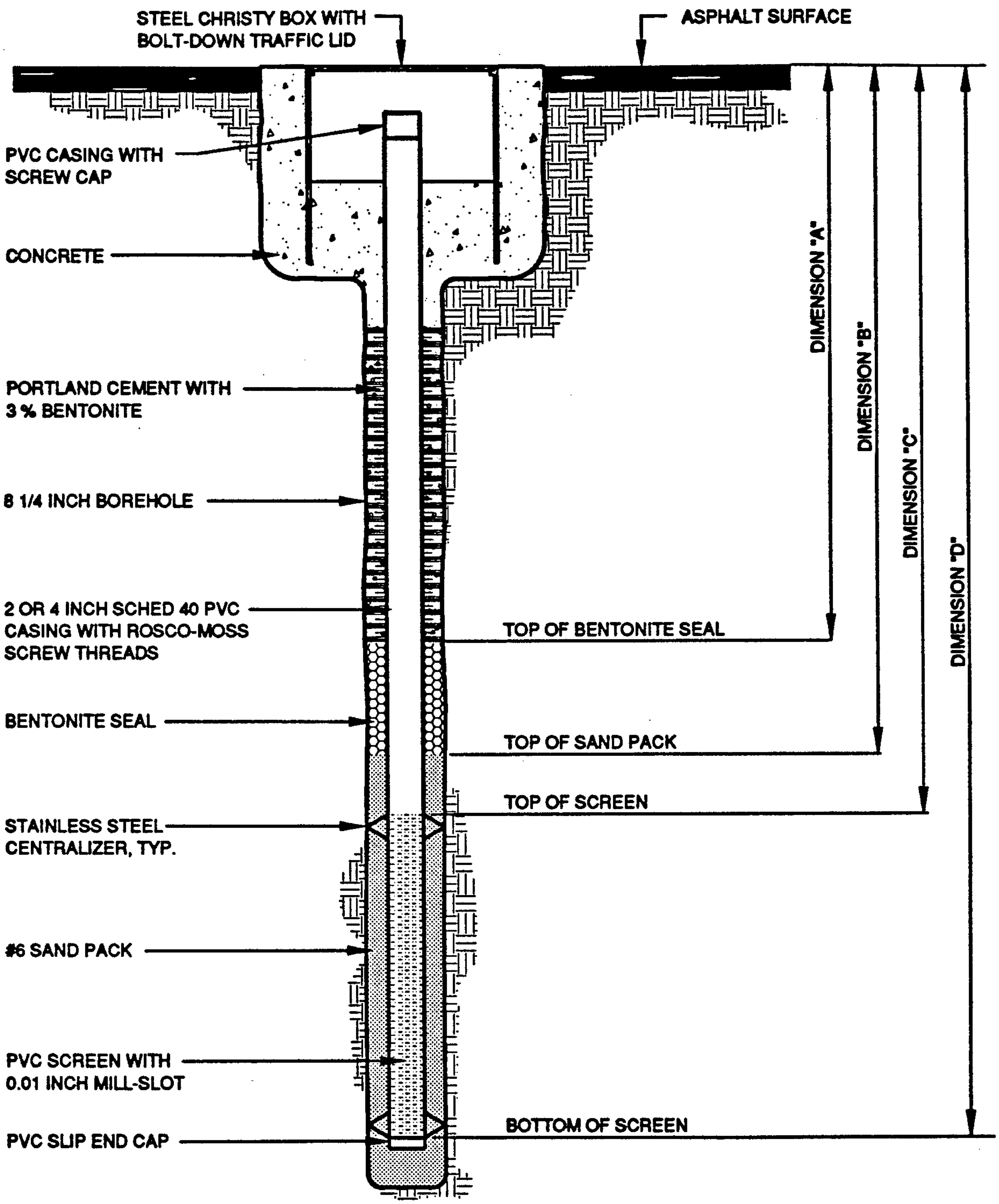
Exact construction details of W-1987-6 and W-1987-7 are not known. These wells are constructed of 2-inch ID Schedule 40 PVC casing with slip caps at the surface. Based on soundings with a weighted tape, neither of the wells had bottom caps.

The screened intervals are reported to be from 14.8 feet to 33.6 feet bgs (W-1987-6) and 8 feet to 35 feet bgs (W-1987-7). During excavation activities in 1992 for installing vaults at the wells, bentonite surface seals were noted. The extent of the bentonite seals below the ground surface is unknown. The type of backfill over the screened intervals is also unknown, but probably consists of native fill. It is unknown if a grout seal exists at either well. The geologic cross-section (Figure 2.3) shows the borehole depths and screened intervals.

3.3 Location and Construction of Additional Soil Vapor Monitoring Well

At the request of the Regional Water Quality Control Board (RWQCB) and McClellan AFB, one additional SVMW will be installed at the site. The primary purpose of this additional well is further characterization of soils below 35 feet, the maximum screened depth for existing wells at the site. The proposed location for this additional well is shown on Figure 3.2. The proposed location was chosen because it is near the location of

FIGURE 3.1



	CP-1	CP-2	CP-3	CP-4	CP-5	CP-6
TOP OF BENTONITE SEAL (A)	11.2	11.4	7.0	7.3	11.5	ABANDONED BY GROUTING
TOP OF SAND PACK (B)	12.8	12.9	8.7	8.8	12.8	
TOP OF SCREEN (C)	15.0	15.8	15.7	10.8	14.7	
BOTTOM OF SCREEN (D)	25.0	25.0	25.7	20.8	19.7	
DIAMETER OF CASING	2 INCHES	2 INCHES	2 INCHES	4 INCHES	2 INCHES	

SOIL VAPOR MONITORING WELL CONSTRUCTION DIAGRAM

CAPEHART GAS STATION

McCLELLAN AIR FORCE BASE, CALIFORNIA

SOURCE: CH2M HILL (1992)

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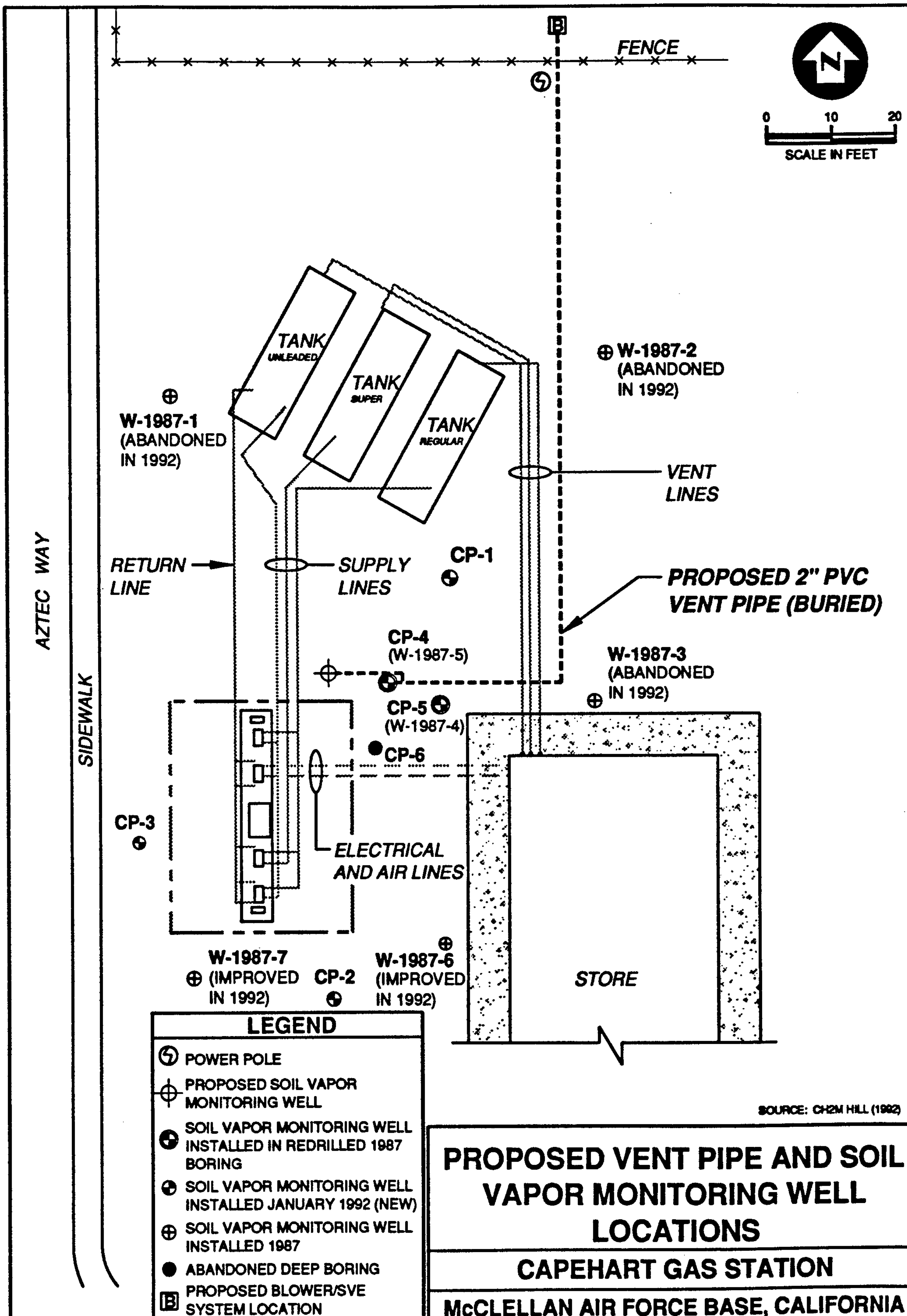
FIGURE 3.2



SOURCE: CH2M HILL (1992)

PROPOSED VENT PIPE AND SOIL VAPOR MONITORING WELL LOCATIONS

CAPEHART GAS STATION

McCLELLAN AIR FORCE BASE, CALIFORNIA

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the former fuel line break and free product discovered in 1987, and it is near CP-4 where elevated soil-gas readings were found during previous sampling events.

The additional SVMW will be constructed similarly to well CP-4, which was discussed in Section 3.2 and shown on Figure 3.1. Additional details of well construction are found in Section 4.0 of the protocol document. However, the top and length of the screened interval will be based on field organic vapor analysis (OVA) of soil sample headspace and downhole soil-gas samples collected during drilling of the borehole. Since the primary purpose of the additional SVMW is to provide characterization of soils below 35 feet bgs, the screen will start at 35 feet bgs or deeper and the borehole will be terminated when field OVA readings and downhole soil-gas samples indicate that the vertical extent of contamination has been identified. The criteria used to determine the extent of vertical contamination is discussed in detail in Section 3.5.2. The bottom of the borehole will then be backfilled with a bentonite seal and the bottom of the screened interval set at the depth where contamination was last identified. If the borehole is advanced to the water table and contamination appears to extend to the water table, the screened interval will also extend to the water table.

Depending on soil and soil-gas results for samples collected during drilling, the additional SVMW may be used as a secondary VEW in addition to CP-4 during the extended (one-year) pilot test, as discussed in Section 3.8.

3.4 Handling of Drill Cuttings

All drill cuttings from the additional borehole will be gathered and containerized on site in labelled U.S. DOT-approved 55-gallon drums. The drums will be placed on pallets provided by McClellan AFB and base personnel will be notified at the end of each day. No drums will be transported off site by ES or the drilling contractor.

3.5 Soil and Soil-Gas Sampling

3.5.1 Soil Sampling

At the request of the RWQCB, two soil samples will be collected during the installation of the additional SVMW. One sample will be collected from the most contaminated interval of the SVMW boring, and one sample will be collected from the bottom of the boring. The soil sample from contaminated soil will be analyzed for TPH-g, BTEX, moisture content, pH, grain size distribution, total alkalinity, iron, and nutrients including total Kjeldahl nitrogen (TKN) and total phosphorus, according to protocol document procedures. The confirmatory soil sample from the bottom of the boring, in presumed clean soil, will be analyzed for TPH-g and BTEX only.

Soil samples will be collected using a split-spoon sampler containing brass tube liners. Soil samples collected in the brass tubes will be immediately trimmed and the ends sealed with Teflon® tape held in place by plastic caps. Soil samples collected for inorganic and physical parameters analysis will also be collected in brass tubes or placed in other appropriate sample containers. Soil samples will also be labeled following the nomenclature specified in Section 5.5 of the protocol document, wrapped in plastic, and placed in an ice chest for shipment. A chain-of-custody form will be filled out and the

ice chest shipped for analysis to PACE, Inc. in Novato, California, which has been audited by the U.S. Air Force and which meets all quality assurance/quality control and certification requirements for the State of California.

A GasTech™ Total Hydrocarbon Vapor Analyzer (THVA) will be used to collect field OVA readings of soil sample headspace. This platinum catalyst combustion detector is calibrated with hexane, which provides a conservative reading representative of total petroleum hydrocarbon vapors present. A 100 ppmv OVA reading of the headspace will be the criterion used in determining whether soils are potentially contaminated.

3.5.2 Downhole Soil-Gas Sampling

At the request of the RWQCB, downhole soil-gas samples will be collected during drilling of the additional SVMW every 10 feet until at least three successive soil-gas samples and soil headspace OVA readings indicate that the vertical extent of contamination has been identified. A soil-gas reading of 100 ppmv or greater using the THVA or an indication of oxygen depletion using a GasTech™ O_2/CO_2 meter will be the criterion used in determining whether the soils are potentially contaminated. The 10-foot interval may be altered in the field in order to provide a better characterization of the lithology at the site. Downhole soil-gas samples will be collected using a soil-gas probe pushed ahead of the drill auger and following procedures similar to those used during drilling by Radian Corporation at the SA 6 bioventing site at McClellan AFB.

At the appropriate depth, the soil-gas probe will be pushed ahead of the drill auger approximately 1 to 2 feet into the native soil. *In situ* soil-gas samples will then be withdrawn for field and laboratory analysis prior to further advancement of the drill auger. After sample collection, the probe will be withdrawn from the borehole so that drilling may continue or soil samples can be collected. The probe will then be decontaminated in preparation for use at the next sampling interval. This downhole technique will allow for a field screening of *in situ* soil gas correlated to depth prior to well completion.

Soil-gas samples will be collected by applying a vacuum using a small air pump at the ground surface. The vacuum and flow will be properly monitored and adjusted to prevent leakage of ambient air into the sampling system. After purging the probe tubing, the tubing and air pump will be connected to a vacuum chamber at the ground surface holding a 3-liter Tedlar sample bag. The chamber will be evacuated with the air pump, filling the Tedlar bag with the soil-gas sample. Individual soil-gas samples for field analysis with hand-held meters and for laboratory analysis using a Summa® cannister will then be immediately withdrawn from the same sample bag. These techniques will minimize purging and sample collection activities, prevent ambient air leakage, and ensure that field and laboratory analysis are performed on the same representative sample.

Soil-gas samples collected for laboratory analysis will be placed in an ice chest and packed to prevent excessive movement during shipment. Samples will not be sent on ice in order to prevent condensation of hydrocarbons. A chain-of-custody form will be filled out and the ice chest shipped to the Air Toxics Ltd. laboratory in Folsom, California for

analysis. Because of the widely varying TPH-g and BTEX concentrations resulting from the Modified EPA Method TO-14 used during previous soil-gas sampling events, the more standard EPA Method TO-3 (unmodified) will be used for all soil-gas samples collected during the bioventing pilot test at the Capehart Gas Station Site. This method is also standard for soil-gas samples collected under the protocol document.

3.5.3 Pilot Test Soil-Gas Sampling

During initial and extended pilot test activities, soil-gas oxygen, carbon dioxide, and total volatile hydrocarbons (TVH) will be monitored with a hand-held GasTech™ O_2/CO_2 meter and the THVA. These instruments and their use are described in more detail in Section 4.5 of the protocol document. Readings will be taken at each SVMW prior to and throughout the initial ISR test, and periodically during the extended (one-year) pilot test. By monitoring the steady-state utilization of oxygen and the steady-state production of carbon dioxide between surrounding VMPs and the extracted soil gas at the VEWs, fuel hydrocarbon biodegradation rates can be estimated and compared with those rates estimated from the initial ISR test. Soil-gas monitoring is more fully discussed in Section 3.8.3.

Prior to the initial ISR test, and again after the extended (one-year) pilot test, soil-gas samples will be collected in Summa® cannisters for laboratory analysis from the SVMWs in order to determine the reduction in TPH-g and BTEX in soil gas over the duration of pilot testing. In addition, similar samples will be collected at the surface emission treatment system during various phases of the extended (one-year) pilot test in order to document reduction of soil-gas emissions by the in-place treatment system. Chain-of-custody procedures for sample storage and shipment will be followed as discussed in Section 3.5.1. System monitoring of the treatment system is more fully discussed in Section 3.8.3.

3.6 Air Permeability Test

As previously mentioned, an AP test will not be performed during the initial pilot test because a similar test was conducted in 1992 by CH2M Hill. The following is a discussion of that test.

The previous AP test was conducted on 11 January 1992 by CH2M Hill to estimate the average air permeability of the subsurface soil and the radius of influence of the VEW (CP-4). Test data and results are included as Appendix C.

The AP test was conducted using CP-4 as a VEW, and CP-1, CP-2, and CP-5 as pressure piezometers. The duration of the test was 1 hour, during which air was extracted from CP-4 at a constant flow rate of approximately 20 standard cubic feet per minute (scfm). A Rotron™ Model 454 air blower was connected directly to the 4-inch ID casing at CP-4 to act as a vacuum source. A mercury manometer was connected to the well-head at CP-4 to measure the applied negative pressure. Water manometers were connected to the 2-inch ID well-heads at CP-1, CP-2, and CP-5 to measure vacuum during the test. Exhaust air from the air blower was piped through a 30-gallon activated-carbon cannister before venting to the atmosphere.

Based on test data, the average air permeability of the soil over the tested depth interval (10 to 25 feet bgs) ranges from approximately 45 to 150 darcys. The geometric mean of three separate air permeability values was 80 darcys.

Based on the steady-state pressure decreases observed in CP-1, CP-2, and CP-5, and the radial distances of these wells from the VEW (CP-4), the radius of influence of the VEW under the conditions of the AP test was estimated at approximately 70 feet.

Over the duration of the test, the concentration of TPH-g in soil-gas increased from 2,900 to 8,100 ppmv. Similarly, benzene levels increased from 17 to 160 ppmv. Increases in soil-gas concentrations of TPH-g and BTEX during AP testing are typical during very early air extraction, although these concentrations tend to decrease with extended air extraction as the initial pore volume of soil gas is removed. It was reported that approximately 18 grams of benzene were removed.

In addition to determining the air permeability of the subsurface soils and the radius of influence based on pressure response, AP tests conducted by ES for bioventing pilot tests also determine the extent of the subsurface that can be oxygenated. For highly-permeable soils, like those found at the Capehart Gas Station Site, the radius of influence based on oxygen response can be significantly larger over a long-term test than the radius of influence determined by pressure response. The radius of oxygen influence was not determined by the previous AP test since no soil-gas oxygen monitoring was performed. This radius of oxygen influence will be determined during the extended (one-year) phase of pilot testing.

3.7 *In Situ* Respiration Test

An ISR test will be performed during the initial pilot test and additional ISR tests will be performed after 6 and 12 months of extended (one-year) pilot testing. The objective of the initial ISR test is to determine the rate at which native soil microorganisms will biodegrade the TPH and BTEX contamination in the soil. The objective of the follow-up ISR tests is to monitor the long-term performance of the bioventing system.

During the initial pilot test, ISR tests will be performed at the SVMWs where biodegradation is indicated by initially low oxygen levels and elevated carbon dioxide levels in the soil gas. A mixture of air and 2 to 4 percent helium will be injected into these SVMWs for approximately 20 hours to oxygenate local contaminated soils. At the end of the 20-hour period, the air/helium supply will be cut off and oxygen, carbon dioxide, total volatile hydrocarbons (TVH), and helium levels will be monitored for the following 48 to 72 hours. The decline in oxygen levels over time will be used to estimate rates of bacterial degradation of fuel residuals. Helium, an inert gas, will be used as a tracer gas and monitored to identify possible system leaks or short circuits to the surface. Additional details on ISR testing are found in Section 5.7 of the protocol document.

During the long-term (one-year) pilot test, ISR tests will be performed by temporarily shutting off the central blower and monitoring oxygen and carbon dioxide levels over time. Data collected will be similarly used to estimate rates of bacterial degradation of fuel residuals.

3.8 Installation of Extended Bioventing Pilot Test System

An extended (one-year) bioventing pilot test system will be implemented at the site if the initial pilot test successfully demonstrates the feasibility of the technology. This one year of continuous operation will determine the long-term radius of oxygen influence and the effect of time and available nutrients on fuel biodegradation rates. The following sections discuss the concept of operations, overview of system design, and system monitoring and evaluation.

3.8.1 Concept of Operations

3.8.1.1 Phase One - Soil Vapor Extraction (SVE) Operations. The first phase of the extended pilot test will focus on removing the initial high levels of volatile hydrocarbons from the soil through the use of a soil vapor extraction (SVE) system with off-gas treatment provided by an internal combustion engine and a catalytic converter. The SVE system will be attached through subsurface piping to the primary VEW (CP-4) and, if completed as a VEW, the additional SVMW described in Section 3.3. A site plan showing the location of the wells, proposed subsurface piping, and surface equipment was shown on Figure 3.2. The SVE system will be operated to achieve mass removal of at least 90% by weight of influent TVH and benzene concentrations as required by the Sacramento Metropolitan Air Quality Management District (SMAQMD). System monitoring is discussed in more detail in Section 3.8.3. The total duration of Phase One is expected to be 60 to 90 days, based on initial concentrations of TPH-g and BTEX in the soil gas and on performance of SVE systems at similar sites. This estimate will be further refined based on the results of the initial pilot test at the site.

3.8.1.2 Phase Two - Bioventing Operations. Phase Two of the extended pilot test will focus on the *in situ* biodegradation of the remaining fuel residuals in the soil. The main feature of Phase Two will be aerating the subsurface soils by applying air injection at CP-4 and the additional SVMW (if completed as a VEW). Potential atmospheric air emissions should be negligible because the asphalt/concrete surface covering the site within the radius of influence of CP-4 and the additional SVMW will prevent vertical soil vapor flow, Phase One operations will have removed the majority of hydrocarbon vapors, and the injection flow rate will be very low (on the order of 20 to 40 scfm). In addition, any remaining hydrocarbon vapors will be biodegraded as they move horizontally through the soil.

During Phase Two operations, air monitoring using a photoionization detector (PID) and a THVA will be performed within surrounding buildings and along any accessible subsurface utilities to verify that hazardous levels of vapors are not migrating to potentially problematic receptors. The low flow rate expected to be implemented for Phase Two will also minimize the potential for producing hazardous levels of vapors at the site.

3.8.2 Overview of System Design

3.8.2.1 Phase One - SVE System. The SVE system proposed for use during Phase One will be designed to remediate petroleum-contaminated soils while maintaining strict California air emission standards. A process and instrumentation diagram is shown in

Figure 3.3. Such systems have been permitted within the State of California at similar sites; however, a site-specific air permit may be required by the SMAQMD.

The proposed system uses an internal combustion engine as a source of vacuum to draw soil vapor from the VEWs into the intake manifold of the engine. The soil vapor is then combusted within the engine, with propane or natural gas used as a supplemental fuel during startup or when hydrocarbon levels in the soil gas are insufficient to keep the engine operating efficiently. The exhaust gas is then passed through a catalytic converter to ensure maximum reduction of hydrocarbons. On-board system analyzers can be added to ensure that engine parameters are adjusted properly and that emissions are minimized. No external power source is required. These systems require minimal maintenance, consisting primarily of resupplying the supplemental fuel tanks and of monitoring engine performance. They are trailer-mounted for ease of transportation and setup.

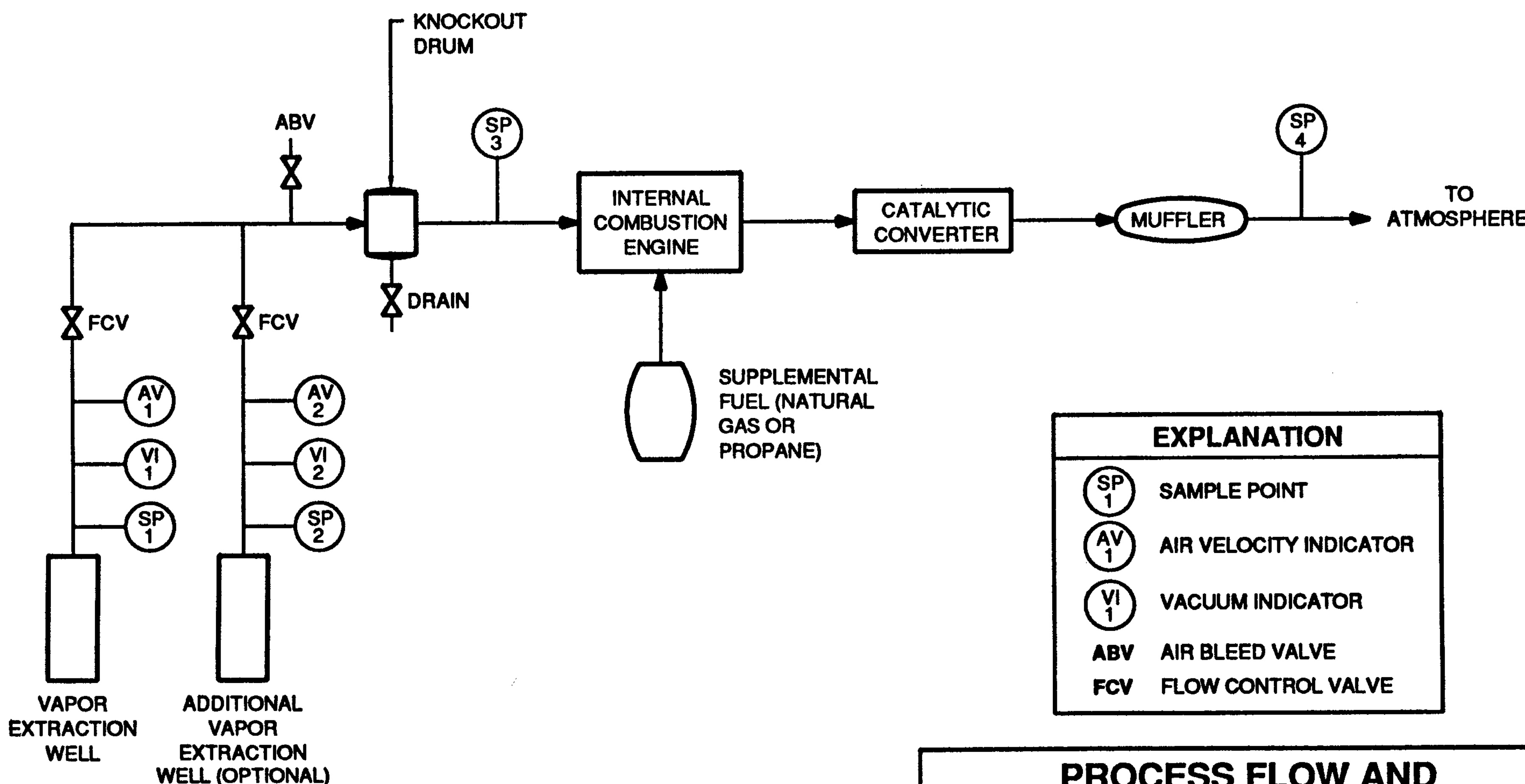
The SVE system will be sized to deliver a flow rate of up to 60 scfm at the expected well-head pressure at the VEWs. A system of this size will remove up to approximately 10 pounds/hour of hydrocarbons at a destruction efficiency exceeding 99%, based on performance at similar sites. Actual operating parameters will be dependent on soil conditions, hydrocarbon concentrations in the extracted soil gas, air emissions requirements, and engine performance.

3.8.2.2 Phase Two - Bioventing System. Following completion of SVE operations, an air injection bioventing system will be installed at the site. The system will be similar to those installed by ES at other bioventing pilot test sites at McClellan AFB. The system will be connected to the VEWs through the same subsurface PVC piping used for SVE operations in Phase One. Based on site soil conditions and the radius of influence calculated from data collected during the previous AP test, a 1.0-horsepower Gast™ regenerative blower (model R4) capable of operating at 20 scfm at a well-head pressure of 50 inches of water will be installed at the site. This flow rate should be sufficient to aerate the soils within a 70-foot radius of the injection points and is low enough to minimize potential vapor migration during Phase Two.

3.8.3 System Monitoring and Evaluation

3.8.3.1 Air Monitoring Plan (Phase One - SVE Operations). During Phase One SVE operations, extracted soil gas entering and treated soil-gas leaving the SVE system will be analyzed for TPH-g and BTEX using procedures similar to those previously described in Section 3.5. These results will be used to tune the SVE system to achieve maximum removal rates, while remaining below air emissions levels required by the SMAQMD. When results of soil-gas analysis indicate that contaminant levels are at or below a target TPH-g concentration that can be biodegraded *in situ* without causing contaminant migration, the SVE system will be shut down and Phase Two bioventing operations will begin. The target level of TPH-g concentration to be used will be based on the ISR test results from the initial pilot test, which will provide an estimate of the biological capacity of the soil volume. Based on bioventing pilot test results from similar sites, this target concentration is expected to be between 500 and 1,000 ppmv TPH-g.

FIGURE 3.3



PROCESS FLOW AND INSTRUMENTATION DIAGRAM FOR SOIL VAPOR EXTRACTION

CAPEHART GAS STATION

McCLELLAN AIR FORCE BASE, CALIFORNIA

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Oxygen, carbon dioxide, and TVH (using the THVA) will be measured in the SVE influent and at all SVMWs in order to screen soil-gas samples for laboratory analysis and verify that oxygen levels in soils increase as a result of SVE operations. A PID and THVA will also be used initially within surrounding buildings and along any accessible subsurface utilities to verify that hazardous levels of vapors are not migrating and to establish baseline conditions. By monitoring the steady-state utilization of oxygen and the steady-state production of carbon dioxide between VMPs at the outer limit of the contaminated soil and the extracted soil gas at the primary VEW (CP-4), fuel hydrocarbon biodegradation rates can be estimated and compared with those estimated from the initial ISR test. If existing VMPs do not provide sufficient data suitable for measurement of the steady-state oxygen utilization, soil-gas probes will be installed outside the area of contamination in order to measure soil-gas concentrations.

Table 3.1 provides a summary of the frequency and type of monitoring to be conducted at each monitoring location during Phase One operations. Monitoring will be most frequent during system startup when the highest levels of volatile hydrocarbons will be extracted from the soil and when performance of the SVE system is being evaluated. Monitoring will then continue on a periodic basis until the target level of TPH-g is reached. After this target level is reached, the SVE system will be shut off and the soil and soil-gas will be allowed to reach equilibrium to verify that soil-gas contamination levels are reduced to appropriate levels for an air injection system.

TABLE 3.1

MONITORING SCHEDULE
(PHASE ONE - SVE OPERATIONS)

Location	Analysis	Frequency
SVE Influent	TPH-g, BTEX (EPA TO-3)	Daily for first three days Weekly thereafter
	O_2/CO_2/TVH (field)	Daily for first three days Weekly thereafter
SVE Effluent	TPH-g, BTEX (EPA TO-3)	Daily for first three days Weekly thereafter
SVE System	Flow rate, Temperature, Auxiliary fuel use	Daily for first three days Weekly thereafter
SVMWs	O_2/CO_2/TVH (field)	Daily for first three days Weekly thereafter
Buildings/ Utilities	TVH (field)	Before system start-up Daily for first three days

3.8.3.2 Air Monitoring Plan (Phase Two - Bioventing Operations). As previously described in Section 3.7, the biodegradation of fuel residuals in the soil will be monitored using ISR tests conducted after 6 and 12 months of operation. These tests will determine how the activity of microorganisms at various points in the contaminated soil volume changes over time and as contamination levels decrease. A PID and THVA will also be used initially within surrounding buildings and along any accessible subsurface utilities to verify that hazardous levels of vapors are not migrating and to establish baseline conditions.

3.8.3.3 One-Year Evaluation. At the end of one year of operation of the air injection bioventing system, ES personnel will return to the site to sample and analyze the soil gas, conduct the final ISR test, and collect soil and soil-gas samples to determine the degree of remediation achieved during the first year of operation. Based on results presented by ES for the first year of pilot-scale bioventing, the Air Force Center for Environmental Excellence (AFCEE) will recommend one of two options:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operations.

2. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the wells.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The following procedures are exceptions to normal protocol as outlined in the protocol document:

- Only one soil boring will be advanced, which will be completed as a SVMW. This additional SVMW may be utilized as a vapor extraction well during the pilot test, depending on results obtained during the field investigation. Existing wells at the site will also be used for pilot testing. A soil-gas probe outside the area of contamination may be installed during the extended (one-year) pilot test.
- No AP test will be conducted. Results from the test conducted in 1992 will be used to complement the bioventing pilot testing.
- The extended (one-year) pilot test will include air extraction with emissions treatment and air injection, and it will also include more system monitoring and evaluation than normal protocol.

The procedures used to conduct the ISR test will be the same as described in the protocol document.

5.0 BASE SUPPORT REQUIREMENTS

The following base support is needed prior to the arrival of the ES test team to perform the additional drilling and the initial ISR test:

- Confirmation of regulatory approval for the initial ISR test. The initial ISR test can be performed prior to the regulatory approval and permitting requirements for the extended pilot test.
- Obtaining a digging permit for the site.
- Installation of a 208-230V/single phase/30 amp breaker box, which meets any locally or Air Force required fire safety codes. The breaker box must include an on-off switch, one 230V receptacle (NEMA type L630), and at least one 110V receptacle. The breaker box must be within 20 feet of the proposed blower location shown on Figure 3.2.

  The initial ISR test could be performed with only the 110V service since an AP test will not be performed and the Phase One-SVE Operations have no power requirements. Therefore, if the site has 110V outlets in the vicinity of the north side of the shoppette building, then electrical installation can be delayed until after the initial ISR test is completed.
- Provide any paperwork required to obtain gate passes and security badges for approximately two ES employees and two drillers.
- Provide a schedule of service station activities, including fueling operations, for planning of field work. Portions of the site will require securing from pedestrian and vehicular traffic during testing activities.
- Provide keys, if necessary, to the existing on-site wells.
- Provide pallets for storing the 55-gallon drums which will hold drill cuttings and arrange for the pick up of the drums at end of drilling.
- Access to a telephone in a building located as near to the site as practical (preferably the gas station store building).
- 24-hour site access and 24-hour access to 110V electrical service.

The following base support is needed prior to the arrival and implementation of the Phase One-SVE Operations:

- Obtaining all necessary regulatory permits for the SVE system, most importantly the air permit which will be required by the Sacramento Metropolitan Air Quality Management District (SMAQMD) before air extraction operations can proceed.
- Installation of the subsurface PVC piping from the primary VEW (CP-4) and the additional SVMW (if completed as a VEW) to the proposed location of the SVE system and bioventing blower (see Figure 3.2). This includes installation of a new surface box for CP-4. Engineering-Science, Inc. will provide a schematic diagram which will show proper subsurface piping design and construction and will provide

the well-head connection piping. The well-head connection piping must fit within the new surface box for future sampling access.

- Obtaining any other needed permission from base and site personnel to conduct SVE and bioventing operations.

During the Phase One-SVE Operations (expected to last 60 to 90 days) and during the Phase Two-Bioventing Operations (one year), the following base support is required:

- During Phase One, base personnel are to check the SVE system once each week to ensure that it is operating properly, record system monitoring information, and notify ES if the supplemental fuel requires resupply. ES will provide a brief operations and maintenance (O&M) training session.
- During Phase Two, base personnel are to check the bioventing system once each week to ensure that it is operating properly and record system monitoring information. Monitoring data must be transmitted to ES once each month. ES will provide an O&M Manual and a brief O&M training session.
- Arrange site access for the ES test team to conduct Phase One operations (see Table 3.1) and Phase Two operations including ISR tests at approximately six months and one year after the initiation of Phase Two-Bioventing Operations.
- If the SVE system (during Phase One) or the bioventing blower (during Phase Two) stops working, notify one of the following people:

Mr. Fred Stanin	(ES Alameda)	at (510) 769-0100
Mr. Michael Phelps	(ES Alameda)	at (510) 769-0100
Mr. Doug Downey	(ES Denver)	at (303) 831-8100
Mr. Patrick Haas	(AFCEE)	at (210) 536-4314

6.0 PROJECT SCHEDULE

The following schedule is contingent upon an initial go-ahead from the regulatory agencies, timely approval of this Draft Addendum, subcontracting and drilling contractors schedules, timely approval by base of digging permits, timely approval of the SVE system design, obtaining the required air permit for SVE operations, timely trenching operations and installation of subsurface piping by base personnel, timely installation of electrical requirements by base personnel, and the estimate of 60 to 90 days for Phase One Operations.

Event	Date
Preliminary Draft Addendum to AFCEE	03 December 1993
Site Visit and Regulatory Meeting	08 December 1993
Follow-up Regulatory Meeting	09 December 1993
Draft Addendum to AFCEE/McClellan AFB	10 January 1994
Approval to Proceed	31 January 1994
Drilling and Well Installation	14 February 1994
Initial ISR Test	21 February 1994
Subsurface Trenching (by base)	28 February 1994
Begin Phase One-SVE Operations	14 March 1994
Begin Phase Two-Bioventing Operations	June 1994
Draft Interim Results Report	To Be Determined
6-Month ISR Test	December 1994
12-Month ISR Test/Soil Sampling	June 1995

7.0 POINTS OF CONTACT

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3200 Peacekeeper Way, Suite 11
McClellan AFB, CA 95652-1036
(916) 643-0830
Fax (916) 643-0827

Mr. Patrick Haas
AFCEE/EST
8001 Inner Circle Drive, Suite 2
Brooks AFB, TX 78235-5328
(210) 536-4314
Fax (210) 536-4330

Mr. Doug Downey
Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290
(303) 831-8100
Fax (303) 831-8208

Mr. Fred Stanin
Mr. Michael Phelps
Engineering-Science, Inc.
1301 Marina Village Parkway, Suite 200
Alameda, CA 94501
(510) 769-0100
Fax (510) 769-9244

8.0 REFERENCES

CH2M Hill 1992, Draft Final Report, Capehart Service Station Site Investigation. April

CH2M Hill 1993a, Final Data Collection Technical Memorandum, Capehart Service Station. August

CH2M Hill 1993b, Telephone conversations between Mr. Michael Phelps of Engineering-Science, Inc and Ms. Kathy McKinley and Ms. Jody Bennett of CH2M Hill Laboratory (Corvallis, OR). 01-02 December

Engineering-Science, Inc. (ES) 1993, Draft Bioventing Pilot Test Work Plan for Tank Farm #2, Tank Farm #4, SA 6, PRL T-46, Building 720, McClellan AFB, CA, and Davis Global Communications Site, Davis, CA. May

Hinchee et al. 1992, Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, United States Air Force Center for Environmental Excellence (AFCEE) and Engineering-Science, Inc. January

Western Geo-Engineers (WEGE) 1987, Letter Report of Soil-Gas Survey, Capehart Housing Service Station. 09 April

APPENDIX A

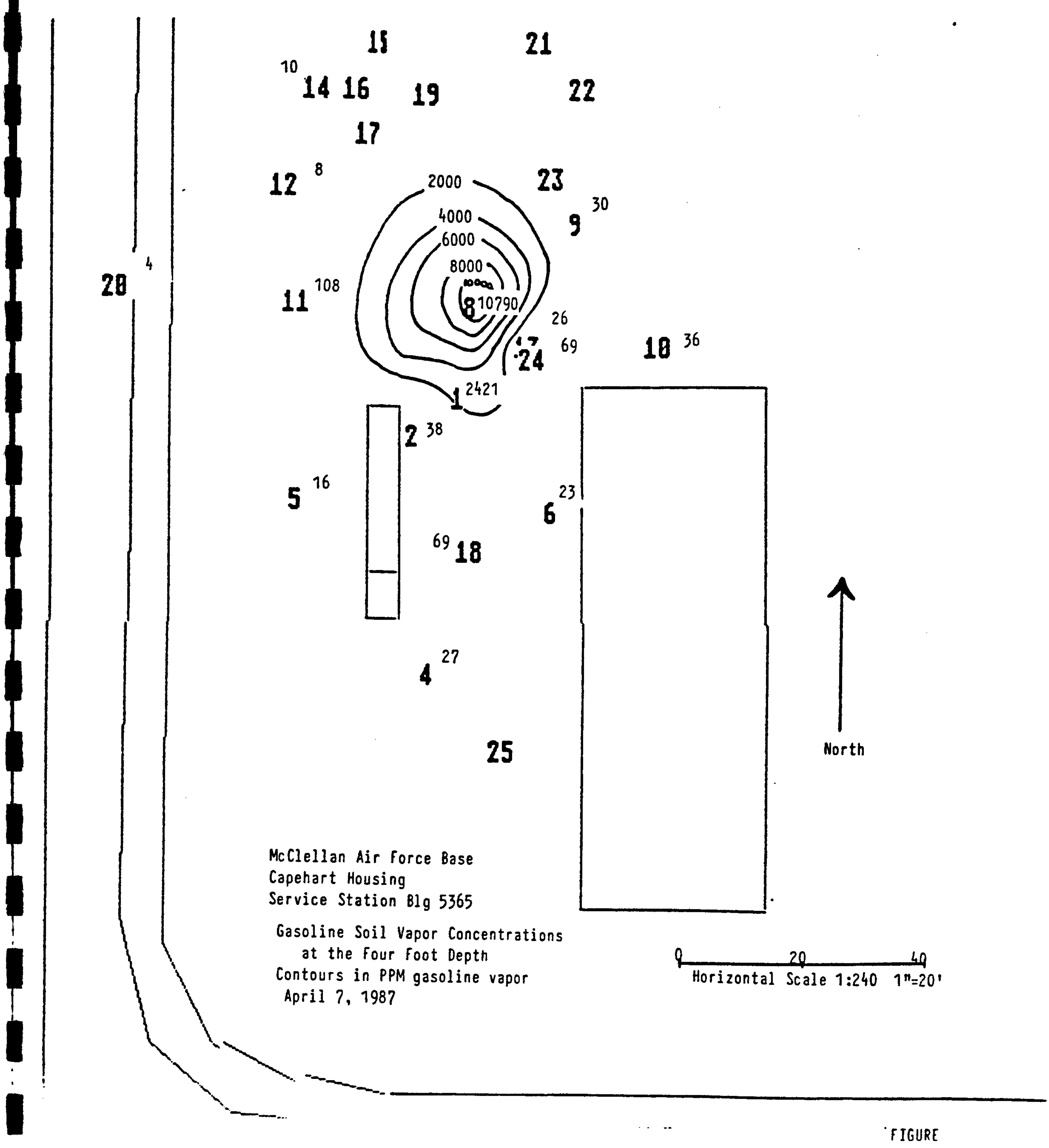
1987 SOIL-GAS SURVEY DATA

TABLE 2

SUBSURFACE SOIL GASOLINE VAPOR READINGS IN PPM

WEGE TEST HOLE	4' Depth PPM	6' Depth PPM	8' Depth PPM	12' Depth PPM	16' Depth PPM	20' Depth PPM
1	2421	------	4946	-------	------	---------
2	38	------	10,390	-------	------	---------
3	69	------	17	-------	------	----------
4	27	------	29	-------	------	----------
5	16	------	132	-------	------	--------
6	23	------	30	-------	------	--------
7	26	------	6034	10,070	15,550	--------
8	10,750	------	13,620	------	------	--------
9	30	------	484	--------	------	--------
10	36	------	30	23	------	--------
11	108	8985	------	-------	------	--------
12	8	20	------	-------	------	--------
13	--------	------	------	-------	------	12,580
14	10	26	------	-------	------	---------
15	-------	------	10	159	134	--------
16	-------	------	9387	9389	------	--------
17	-------	------	565	273	------	--------
18	-------	-------	42	29	3172	5095
19	-------	-------	49	79	------	--------
20	16	39	-------	------	------	--------
21	-------	-------	127	8	------	--------
22	-------	-------	1112	418	------	--------
23	-------	-------	98	2722	------	--------
24	-------	-------	3189	-----	------	--------
25	-------	-------	-------	6	9	--------

- *WEGE* -
WESTERN GEO-ENGINEERS

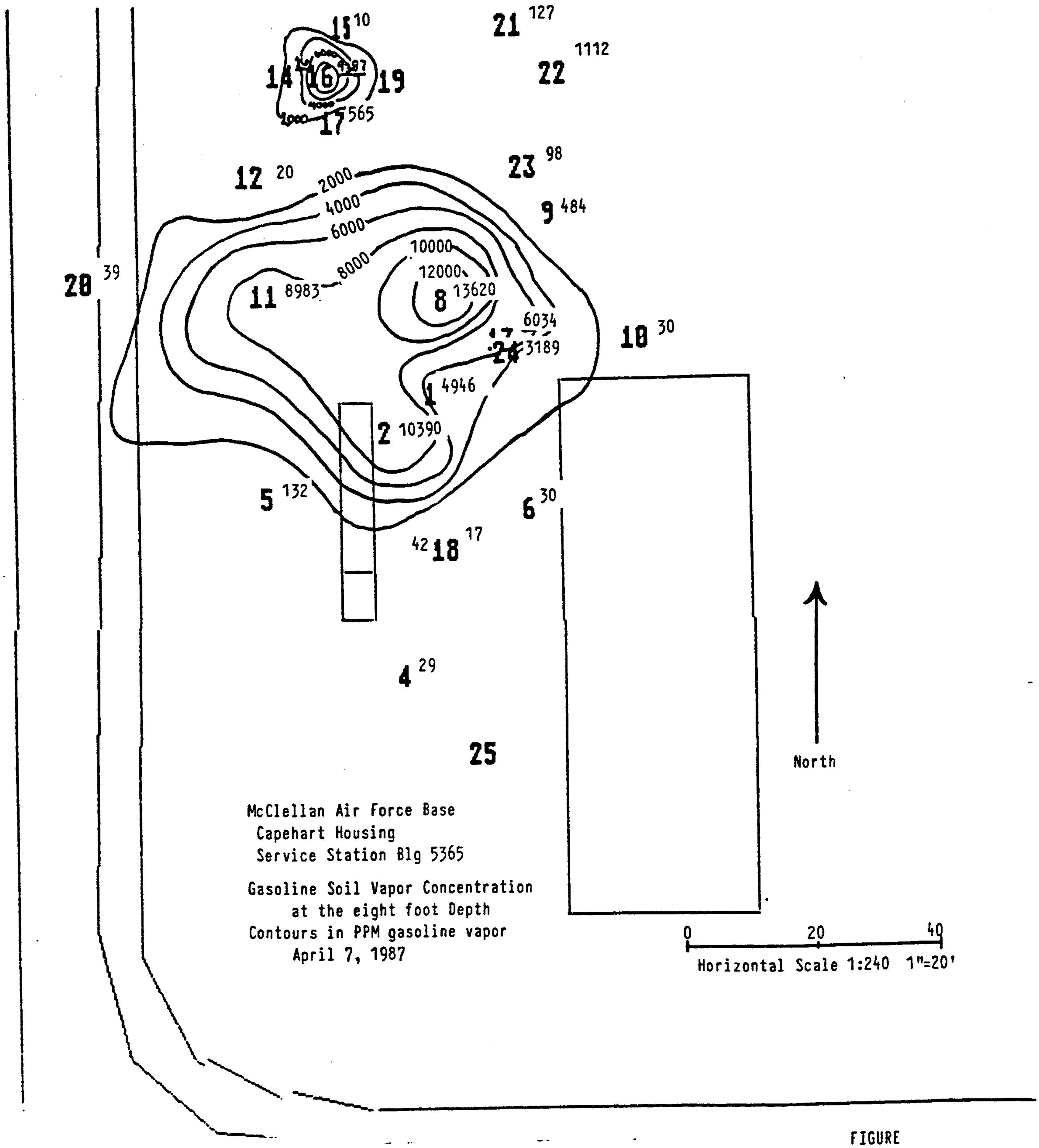


McClellan Air Force Base
Capehart Housing
Service Station Blg 5365

Gasoline Soil Vapor Concentrations
at the Four Foot Depth
Contours in PPM gasoline vapor
April 7, 1987

FIGURE

- WEGE -
WESTERN GEO-ENGINEERS

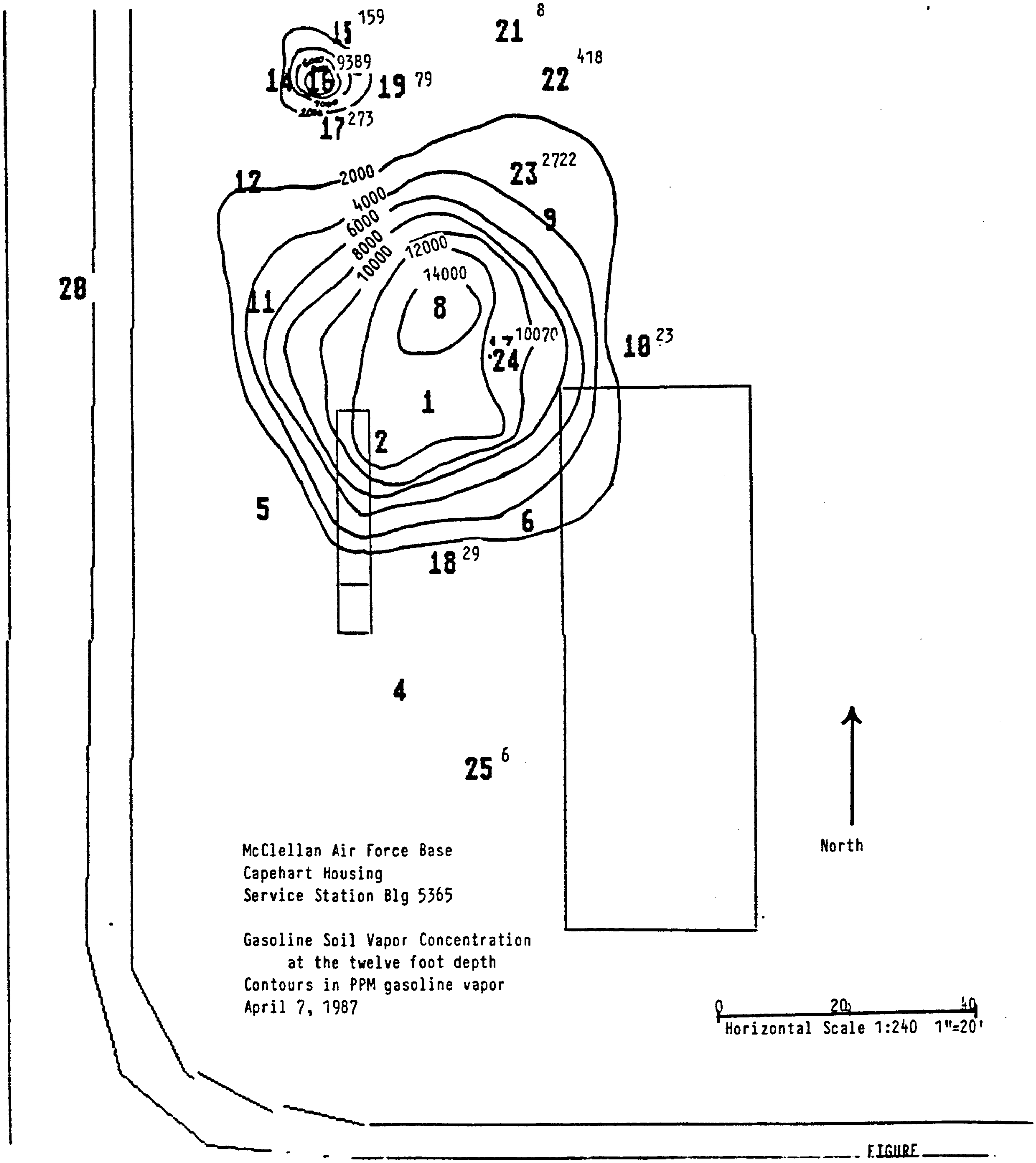


McClellan Air Force Base
Capehart Housing
Service Station Blg 5365

Gasoline Soil Vapor Concentration
at the eight foot Depth
Contours in PPM gasoline vapor
April 7, 1987

FIGURE
9

- *WEGE* -
WESTERN GEO-ENGINEERS



McClellan Air Force Base
Capehart Housing
Service Station Blg 5365

Gasoline Soil Vapor Concentration
at the twelve foot depth
Contours in PPM gasoline vapor
April 7, 1987

FIGURE
10

APPENDIX B

1992 SOIL BORING LOGS

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
SAC28722.24.FI	CP-1	SHEET 1 OF 1

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION NE of Pump Island

ELEVATION ______ DRILLING CONTRACTOR Beylik Drilling

DRILLING METHOD AND EQUIPMENT Mobil B-61 w/8" O.D. HSA & Downhole Hammer

WATER LEVELS Not Encountered START 12:50 1/6/92 FINISH 17:30 1/6/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY	MODIFIED CALIFORNIA TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
	5.0				Asphalt, approximately 1-1/2" thick. AGGREGATE BASE: 1" minus, angular. Cuttings: SILT (ML), moderately plastic, stiff, moist to wet, brown.	HNU=0.2 ppm in auger
5.0	6.5	SS-1	1.2	20-53-50/6	SANDY SILT (ML), very fine sand, brown with some iron staining low plasticity, very stiff.	HNU=112 ppm on sample
	8.0	SS-2	1.5	18-30-50/6	SILT (ML), hard, friable, brown with some iron staining, SAND, medium (SP), dark brown to black, loose, with little silt; silt similar to above in bottom 6".	
	10.0					Drilling moderately slow
10.0	12.0	SS-3	1.5	20-15-41 (56)	SILT (ML), hard, generally friable, light brown with iron mottling, moist; with an approximately 3" seam of SAND (SP) at approximately 11.5'.	
	13.0					Sand similar to above
	14.0	SS-4	1.4	12-37-72/5	SILT (ML), stiff, micaceous, moist, brown with rust staining, moderately plastic in tip and bottom 6".	
	15.0					Gasoline odors from cuttings
15.0	16.0	SS-5	1.5	37-67/4	SILT (ML), friable, brown, stiff, grading to hard and very hard, with grey-green coloring and gasoline odor, with fine sand.	
	17.6				SILT (ML), hard and friable, with grey-green coloring and gasoline odor, with fine sand, becoming harder in tip.	
	19.1	SS-6	1.4	20-47-57/5	Similar SILTY SAND (SM), grading to SILT (ML) with fine sand, grey-green, moist, friable to blocky and hard, less odor than above.	HNU=15 ppm
	20.0					
20.0	21.6	SS-7	1.4	14-25-50/5	SAND (SP), with little silt, dark grey, moderately dense, moist; with SILT (ML), very hard, blocky, grey, little odor.	
	23.3					
	24.3	SS-8	1.0	43-60/6	SANDY SILT (ML), dark grey, friable with some clay; with SILTY SAND (SM), brown, friable, blocky, little odor.	
	25.0					
25.0	25.8	SS-9	1.0	47-60/5	SILTY SAND (SM), dark grey, hard, with hard silt layers. Little apparent odor.	Approximately 1-1.5' thick sand zone-sharp horizon
					Bottom of hole 25.8'	HNU= approximately 3 ppm

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
SAC28722.24.FI	CP-2	SHEET 1 OF 1

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION SE of Pump Island

ELEVATION ______ DRILLING CONTRACTOR Beylik Drilling

DRILLING METHOD AND EQUIPMENT Mobil B-61 w/8" O.D. HSA & Downhole Hammer

WATER LEVELS Not Encountered START 09:00 1/7/92 FINISH 1/7/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE			MODIFIED CALIFORNIA TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
					Asphalt paving, approximately 2-1/2" thick. SANDY SILT (ML), stiff, moist, brown, moderate plasticity.	
5.0	5.0 6.5	SS-1	0.8	31-50/5"	SILTY SAND (SM), very fine, brown, moist, no apparent odor with SANDY SILT (ML).	HNU=25 ppm on sample Drilling harder at approximately 7'
	8.0 9.0	SS-2	1.0	10-65/6"	SANDY SILT (ML), very fine sand, brown with iron staining; grading to SILTY SAND (SM), very fine, sand, dense to very dense, brown, moist, no apparent odor.	HNU lamp fogged
10.0	10.0 10.8	SS-3	0.8	32-67/4"	SILTY SAND (SM), dense to hard, brown with iron staining, moist, no apparent odor. Cuttings: Sand with silt, fine brown.	Driller reports sand horizon at 11.5'
	13.0 13.9	SS-4	0.7	16-50/5"	SAND (SP) with silt, fine, grey, no apparent odor. SANDY SILT (ML), dense to hard, brown with rust staining, moist, moderate plastic, no apparent odor.	Apparent sand horizon
15.0	15.0 17.0	SS-5	1.7	32-46-38 (84)	SAND (SP) with silt, dense, brown, fine, moist, interlayed with SANDY SILT (ML), and SILTY SAND (SM), silt fines are low plasticity, sand is fine, layers are generally less than 3" thickness.	HNU=20 ppm Interlayered sands and silts Driller reports sand layer at 17.5'
	18.0 19.4	SS-6	1.4	27-34-50/5	SAND (SP) with silt, fine to medium, moist, dark brown to black, micaceous, moderately dense, no apparent odor, silt content and gradation vary in layers (approximately 2" thick).	
20.0	20.3 21.3	SS-7	1.0	48-69/6"	SILT with fine sand (ML), hard, friable, moist, no apparent odor, low plasticity fines. Cuttings: Silty CLAY with fine sand (CL-ML), very stiff.	Sand horizon ends at approximately 20.5' Slow drilling
	23.2 24.2	SS-8	1.0	24-50/6"	SILT (ML) with some clay and fine sand, friable, moist, moderately plastic, no apparent odor, a few approximately 1" seams of hard silt, brown and light brown; also a few seams of SILTY SAND, fine, poorly graded.	
25.0	25.0 26.5	SS-9	1.4	20-50-76 (126)	SILT (ML), with some fine sand, low plasticity, hard, friable, light brown, moist, no apparent odor. Bottom of hole 26.5'	

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
SAC28722.24.FI	CP-3	SHEET 1 OF 2

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION W side of Pump Island

ELEVATION DRILLING CONTRACTOR Beylik Drilling

DRILLING METHOD AND EQUIPMENT Mobil B-61 w/8" O.D. HSA & Downhole Hammer

WATER LEVELS Not Encountered START 14:20 1/7/92 FINISH 1/8/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	MODIFIED CALIFORNIA TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
					Asphalt paving approximately 2-1/2" thick.	Using EMC HNU-2
					Aggregate base approximately 3" thick, 1" minus gravel.	HNU=1 ppm
					Cuttings: SANDY SILT (ML), moist, brown, dense.	
					Similar	
5.0	5.0–6.5	SS-1	1.0	40-70/6	SILTY SAND (SM), dense, moist, fine-grained, micaceous, moderate yellowish brown.	HNU=14.7 ppm (sample in baggie)
					Cuttings: Similar, with some clay.	HNU=15.4 ppm (baggie sample)
	8.3–9.1	SS-2	1.0	34-70/4	SILT (ML) with fine sand, grading to SANDY SILT (ML), fine, moist, a few hard, blocky seams approximately 1/4" thick, dense, friable, moderate yellowish brown.	Driller reports sand horizon at approximately 10'.
10.0	10.0–11.3	SS-3	1.1	15-49-50/3	SAND (SP), fine to medium, dense, moist, black grading to yellowish- brown, micaceous.	HNU=14.8 ppm (baggie sample)
	13.0–13.9	SS-4	0.9	39-60/5	SAND (SP), fine to medium, dense, moist, yellow-brown, micaceous, color was black in approximately 2" seam at approximately 13.3', moderate fuel-odor.	HNU=15.2 ppm (baggie sample)
15.0	15.0–16.0	SS-5	1.0	26-74/6		HNU=22.0 ppm (baggie sample) Sand horizon at approximately 15.3
					SAND (SP), similar to above, SILTY SAND (SM) grading to SANDY SILT (ML), dense, friable, low plasticity, moist yellow-brown, faint fuel odor.	Slower drilling HNU=33 ppm (baggie)
	18.0–19.9	SS-6	1.5	40-43-50/5	SAND (SP) with silt, fine to medium, micaceous, moist, with pockets of silt, moderately dense, with fuel odor, yellow-brown.	
20.0	19.9–21.4	SS-7	1.3	20-34-50/5	Similar SAND as above grading to SILT with fine sand (ML), stiff to to hard, friable, moist, low to moderate plasticity, yellow-brown.	HNU=70 ppm (baggie)
	23.0–23.9	SS-8	0.9	12-50/5	SILT with fine sand (ML), stiff to hard, friable, moist, low plasticity, brown, with a seam of SILT (ML), grey, moderately plastic, moderate fuel odor.	HNU=58 ppm (baggie)
25.0	25.0–25.8	SS-9	0.7	18-68/4	SANDY SILT (ML), stiff to hard, blocky, friable, moist, brown, fine sand, some clay.	HNU=78 ppm (baggie) End day at 25.0' 1/7/92 17:45
	28.0–29.4	SS-10	1.0	23-45-60/5	SAND (SP), with silt, fine, moderately dense, yellowish-brown; grading to CLAYEY SILT (CL-ML) with fine sand, moderately plastic, very stiff, to hard, blocky, mostly friable with hard fragments.	Resume 08:00 1/8/92 harder drilling HNU=98 ppm (baggie) driller reports sand approximately 1' thick approximately 28'

CH2M HILL

PROJECT NUMBER	BORING NUMBER
SAC28722.24.FI	CP-3

SHEET 2 OF 2

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION W side of Pump Island

ELEVATION DRILLING CONTRACTOR Beylik Drilling

DRILLING METHOD AND EQUIPMENT Mobil B-61 w/8" O.D. HSA & Downhole Hammer

WATER LEVELS Not Encountered START 14:20 1/7/92 FINISH 1/8/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	MODIFIED CALIFORNIA TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
	30.6	SS-11		50-70/2	CLAYEY SILT with sand (CL-ML), very hard, yellowish-brown, moist; SAND (SP), with silt, fine, dense, yellowish-brown, moist.	HNU=30 ppm Sand in bottom 4" of sampler
					Bottom of hole 33.0'	
35.0						
40.0						
45.0						
50.0						
55.0						

CH2M HILL

PROJECT NUMBER	BORING NUMBER
SAC28722.24.FI	CP-4 SHEET 1 OF 1

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION Reamed W-1987-5

ELEVATION ______ DRILLING CONTRACTOR Beylik Drilling

DRILLING METHOD AND EQUIPMENT Mobil B-61 w/8" O.D. HSA & Downhole Hammer

WATER LEVELS Not Encountered START 1/8/92 FINISH 1/8/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE			MODIFIED CALIFORNIA TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
					Reaming existing hole/well. Cuttings: SILT with fine sand, some clay, moderately plastic, moist, yellowish-brown.	Existing PVC 19.0' bgs screened at approximately 1' bgs Driller reports PVC probably originally installed in 3" diameter boring
					4' similar, moister and darker.	
5.0						
					At approximately 8' CLAYEY SILT (CL-ML) with some gravel, moderately plastic, moist, brown, with fuel odor.	HNU=30 ppm in cuttings drum
10.0						
					At approximately 12' SAND (SP) with silt, brown, moist.	
15.0						
						Driller reports sand at approximate , 18'
20.0	20.0					
	21.4	SS-1	1.4	18-25-50/5	SAND (SP) with some silt, dense, moist, brown, with fuel odor, grading to SILT with some fine sand (ML), low to moderate plasticity, moist, brown, fuel odor, hard friable.	HNU=300 ppm (baggie) very slow drilling
	22.2					
	23.5	SS-2	1.4	15-47-34 (81)	SILTY SAND (SM), fine, dense, friable, with hard layers at approximately 1/4" thick, moist, brown.	
					Bottom of hole 23.5'	
25.0						HNU=50 ppm (baggie)
						No evidence of grout or bentonite sea around old well casing

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
SAC28722.24.FI	CP-5	SHEET 1 OF 1

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION Reamed W-1987-4

ELEVATION DRILLING CONTRACTOR Beylik Drilling

DRILLING METHOD AND EQUIPMENT Mobil B-61 w/8" O.D. HSA & Downhole Hammer

WATER LEVELS Not Encountered START 1/9/92 FINISH 1/9/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	MODIFIED CALIFORNIA TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
					Reaming existing hole/well.	Existing PVC 20.0' bgs
					Cuttings: CLAYEY SILT (CL-ML), with fine sand, moderate plastic, brown, no noticeable fuel odor.	Driller reports PVC probably originally installed in 3" diameter boring
5.0						
					Cuttings: Similar to above, with faint fuel odor.	
10.0					Cuttings: CLAYEY SILT (CL-ML) to SILTY CLAY (CL) with fine micaceous sand, moist, brown, faint fuel odor.	HNU=background (at borehole)
					SAND (SP), approximately 1' thick layer.	Driller reports sand at approximately 13' bgs, fuel odor, probably 1' thick layer
15.0					Cuttings: CLAYEY SILT (CL-ML) to SILTY CLAY (CL) with fine micaceous sand, moderate plastic, moist; greyish-green (stain) with fuel odor.	
20.0	20.0–20.8	SS-1	0.7	35-70/4"	SILTY SAND (SM) and SILT with sand (ML), dense, fine sand, greenish-grey (stain); grading to SILT with fine sand (ML), very hard, moist, brown.	HNU=70 ppm (baggie)
					Bottom of hole 20.8'	No reaction with dilute HCL
						No evidence of grout or bentonite seal around old well casing
25.0						
	30.0					

CH2M HILL

PROJECT NUMBER	BORING NUMBER	
SAC28722.24.FI	CP-6	SHEET 1 OF 4

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION NE Corner of Canopy
ELEVATION DRILLING CONTRACTOR Beylik Drilling
DRILLING METHOD AND EQUIPMENT Mobil B-61 with Downhole Hammer
WATER LEVELS Not Encountered START 11:00 1/10/92 FINISH 1/10/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE: INTERVAL	SAMPLE: TYPE AND NUMBER	SAMPLE: RECOVERY	MODIFIED CALIFORNIA TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
					Asphalt paving Aggregate Base, 1" minus SILTY SAND (SM), fine, micaceous, dark yellowish-brown, moist.	No apparent odor
	4.0				Cuttings approximately 3': SANDY SILT (ML), fine, moderate plastic, moist, light yellowish-brown.	No apparent odor
5.0	5.5	SS-1	1.4	5-25-43 (68)	SILT (ML), with fine micaceous sand, stiff, moist, yellowish- brown, moderately plastic.	HNU=25 ppm (baggie)
	6.0					
	7.5	SS-2	1.4	4-21-50 (71)	SILTY SAND (SM) and SANDY SILT (ML), fine, micaceous, moist, with layers (approx. 1/4"-1/2") of hard silt (no reaction to dilute HCL), with iron staining. SM & ML are dense.	HNU=30 ppm (baggie)
	9.0					HNU=12 ppm (baggie)
10.0	10.5	SS-3	1.3	4-26-26 (52)	SANDY SILT (ML), fine sand, moist, brown, with rust staining, with thin layers of hard silt, grading to SAND (SP) with some silt, fine to medium, dense, dark brown, and black, moist, micaceous.	
	12.0					Strong fuel odor HNU=79 ppm
	13.3	SS-4	1.2	14-24-50/4	SILT (ML) with fine sand, stiff, yellow-brown, moist, low plasticity.	
	14.0					HNU=400 ppm (baggie)
15.0	15.4	SS-5	1.4	19-30-50/5	SANDY SILT (ML), stiff with layers (1/4"-1/2" of hard silt), moist, yellow-brown, fuel odor.	
	17.0					HNU=350 ppm (baggie)
	18.5	SS-6	1.5	6-14-16 (30)	SILT with fine sand (ML) grading to SAND (SP) with some silt, fine to medium, moist, moderately dense, micaceous, with fuel odor, approximately 1/4" thick yellowish-brown layer in bottom 6".	
	19.6					
20.0	21.1	SS-7	1.0	10-26-35 (61)	SAND with silt (SP) grading through SILTY SAND (SM) to SILT (ML) with fine sand, very stiff to hard.	
	22.0					HNU=450 ppm (baggie)
	23.5	SS-8	1.5	5-5-5 (10)	SILT (ML), with fine sand, hard, blocky, greenish-grey, friable, color grading to yellowish-brown with depth.	
	24.1					
25.0	25.6	SS-9	1.2	3-4-8 (12)	SILT (ML), with fine sand, stiff to hard, moist, yellow-brown, grades to harder with depth.	
	27.8					HNU=180 ppm (baggie)
	29.5	SS-10	1.2	6-14-30 (44)	SILTY SAND (SM), fine to medium, moderately dense, moist, grading to SANDY SILT (ML), fine, stiff, friable, grayish-olive.	HNU=110 ppm (baggie)

CH2M HILL

PROJECT NUMBER	BORING NUMBER
SAC28722.24.FI	CP-6

SHEET 2 OF 4

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION NE Corner of Canopy

ELEVATION DRILLING CONTRACTOR Beylik Drilling

DRILLING METHOD AND EQUIPMENT Mobil B-61 with Downhole Hammer

WATER LEVELS Not Encountered START 11:00 1/10/92 FINISH 1/10/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	MODIFIED CALIFORNIA TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
	30.8	SS-11	1.3	10-47-50/4	SANDY SILT (ML), hard, blocky, olive and brown, fine sand, grading to SILTY SAND (SM) in tip	
35.0	34.8–36.2	SS-12	1.4	11-31-50/5	SANDY SILT (ML), fine sand, low to moderate plasticity, moist, yellowish-brown, with approximately 1/4" layers of hard silt.	HNU=130 ppm (baggie)
40.0	39.5–40.9	SS-13	1.4	8-17-25 (42)	SAND (SP) with silt and SILTY SAND (SM), dense, brown, ~~moist~~, fine to medium grading to SANDY SILT (ML) in tip.	HNU=110 ppm (baggie)
45.0	45.0–46.3	SS-14	1.4	15-39-50/4	SANDY SILT (ML), stiff, moderately plastic, moist, brown, grading sandier with depth, with approximately 1/2" thick layers of hard silt	Fished out pin HNU=200 ppm
50.0	49.0–50.5	SS-15	1.1	4-6-10 (16)	SANDY SILT (ML), blocky, hard layers interbedded with stiff layers, approximately 1/4" to 1/2" thick, moist, brown	HNU=130 ppm
55.0	54.0–55.5	SS-16	1.0	4-10-16 (26)	CLAYEY SILT (CL-ML), stiff, with fine sand, brown, moist with hard layers of silt approximately 1/4" thick, plastic.	Winch fouled HNU=300 ppm
	59.6					HNU=350 ppm

PROJECT NUMBER	BORING NUMBER	
SAC28722.24.FI	CP-6	SHEET 3 OF 4

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION NE Corner of Canopy

ELEVATION - - --- DRILLING CONTRACTOR Beylik Drilling

DRILLING METHOD AND EQUIPMENT Mobil B-61 with Downhole Hammer

WATER LEVELS Not Encountered START 11:00 1/10/92 FINISH 1/10/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE			MODIFIED CALIFORNIA TEST RESULTS	SOIL DESCRIPTION	COMMENTS
	INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DEPTH OF CASING, DRILLING RATE DRILLING FLUID LOSS TESTS AND INSTRUMENTATION
	61.1	SS-17	1.2	4-8-16 (24)	SILT with fine sand (ML), blocky, low plasticity, light brown, moist.	
65.0	64.5 – 66.0	SS-18	1.0	11-23-26 (49)	SILTY SAND (SM), fine, dense, brown with iron staining, some thin layers < 1/4" layers of hard silt, moist.	HNU=275 ppm (baggie)
70.0	69.5 – 71.0	SS-19	1.1	8-15-26 (41)	SILT (ML) with clay and some fine sand, blocky, friable, ~~hard~~, moist brown.	HNU=175 ppm
75.0	74.5 – 76.0	SS-20	1.2	4-5-9 (14)	CLAYEY SILT (CL-ML) with SILTY CLAY (CL), stiff plastic, yellowish- grey, moist, little fine sand.	HNU=35 ppm
80.0	79.0 – 80.5	SS-21	1.2	3-2-9 (11)	CLAYEY SILT (CL-ML) with fine sand, stiff, moist, yellowish grey, plastic.	HNU=55 ppm (baggie)
85.0					No sample collected.	Swivel broke, lost hammer down the hole, will retrieve tomorrow
	89.6					Hammer retrieved, resume [illegible]

CH2M HILL

PROJECT NUMBER	BORING NUMBER
SAC28722.24.FI	CP-6

SHEET 4 OF 4

SOIL BORING LOG

PROJECT Capehart Gas Station LOCATION NE Corner of Canopy

ELEVATION ______ DRILLING CONTRACTOR Beylik Drilling

DRILLING METHOD AND EQUIPMENT Mobil B-61 with Downhole Hammer

WATER LEVELS Not Encountered START 11:00 1/10/92 FINISH 1/10/92 LOGGER L. Krook

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE TYPE AND NUMBER	SAMPLE RECOVERY	MODIFIED CALIFORNIA TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION
	91.1	SS-22	1.3	2-9-19 (28)	CLAYEY SILT (CL-ML) with fine sand, very stiff to hard, blocky, moderately plastic, yellowish-grey.	HNU=120 ppm
	94.7					
95.0	96.2	SS-23	1.5	9-23-38 (61)	SANDY SILT (ML) and SILTY SAND (SM), stiff to very stiff, moist, brown, fine to medium sand, (ML) moderately plastic.	HNU=130 ppm
	99.7					
100.0	101.2	SS-24	1.4	12-28-26 (54)	SAND with silt (SP), fine to medium, moist, very dense, brown.	HNU=100 ppm
105.0	105.6					
	107.1	SS-25	1.2	7-22-45 (67)	Similar, with coarser sand, moister.	HNU=90 ppm (baggie)
	108.6				Similar	
					Bottom of hole 108.6'	
110.0	110					
		SS-11	1.3	10-47-50/4		
115.0	115					

DRAFT

APPENDIX C

1992 AIR PERMEABILITY TEST RESULTS

Air Permeability Test

Air Permeability (k)

As described in the text, an in situ air permeability test was conducted using one extraction well and three pressure piezometers. Air was removed from the extraction well at a constant flow rate, and pressure decreases were measured at each of the three observation wells over the test duration of approximately 1 hour. Field data collected during the test are shown in Table F-1. Plots of pressure decreases versus time are shown in Figures F-1 and F-2. Horizontal air permeabilities were calculated using the following equation:

$$k = \frac{r^2 \theta_a \mu}{4\ P_{atm}} \exp\left(\frac{B}{A} + 0.5772\right)$$

where:

k	=	soil permeability to air flow [cm^2]
r	=	radial distance from extraction well to observation well [cm]
θ_a	=	air-filled soil void fraction [dimensionless]
μ	=	viscosity of air [$1.8 \times 10^{-4} \frac{g}{cm\text{-}sec}$]
P_{atm}	=	ambient atmospheric pressure [$1.0\ atm = 1.013 \times 10^{-6} \frac{g}{cm\text{-}sec^2}$]
A	=	slope of P' vs. ln(t) plot [$\frac{g}{cm\text{-}sec^2}$] (Figure F-2)
B	=	y-intercept of P' vs. ln(t) plot [$\frac{g}{cm\text{-}sec^2}$] (Figure F-2)
P'	=	gauge pressure measured at distance r and time t

Reference: P. C. Johnson, M. W. Kemblowski, J. D. Colthart, D. L. Byers, and C. C. Stanley; "A Practical Approach to the Design, Operation, and Monitoring of In-Situ Soil Venting Systems", *Soil Vapor Extraction Technology Reference Handbook*, Environmental Protection Agency, February 1991.

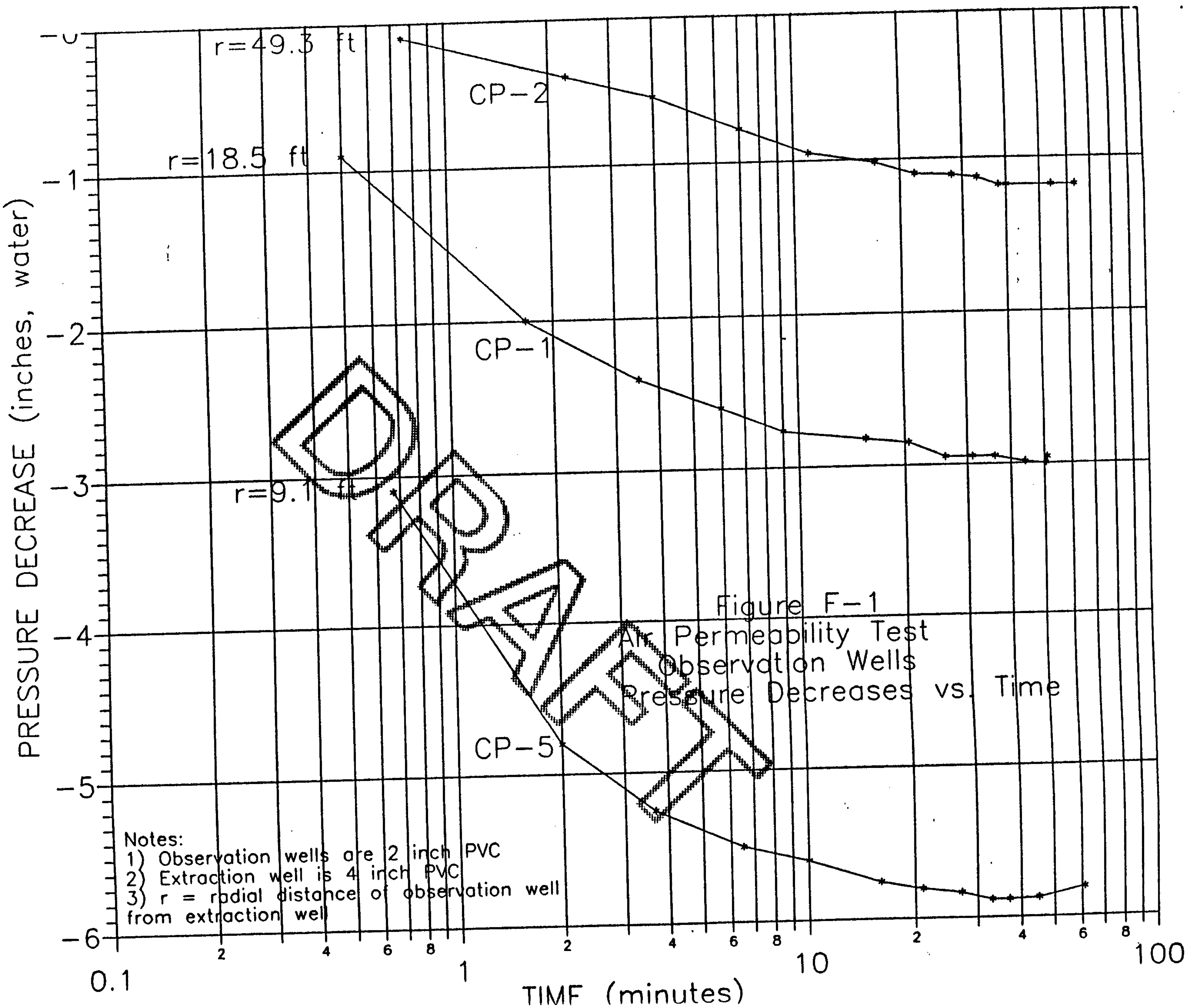


Figure F-1
Air Permeability Test
Observation Wells
Pressure Decreases vs. Time

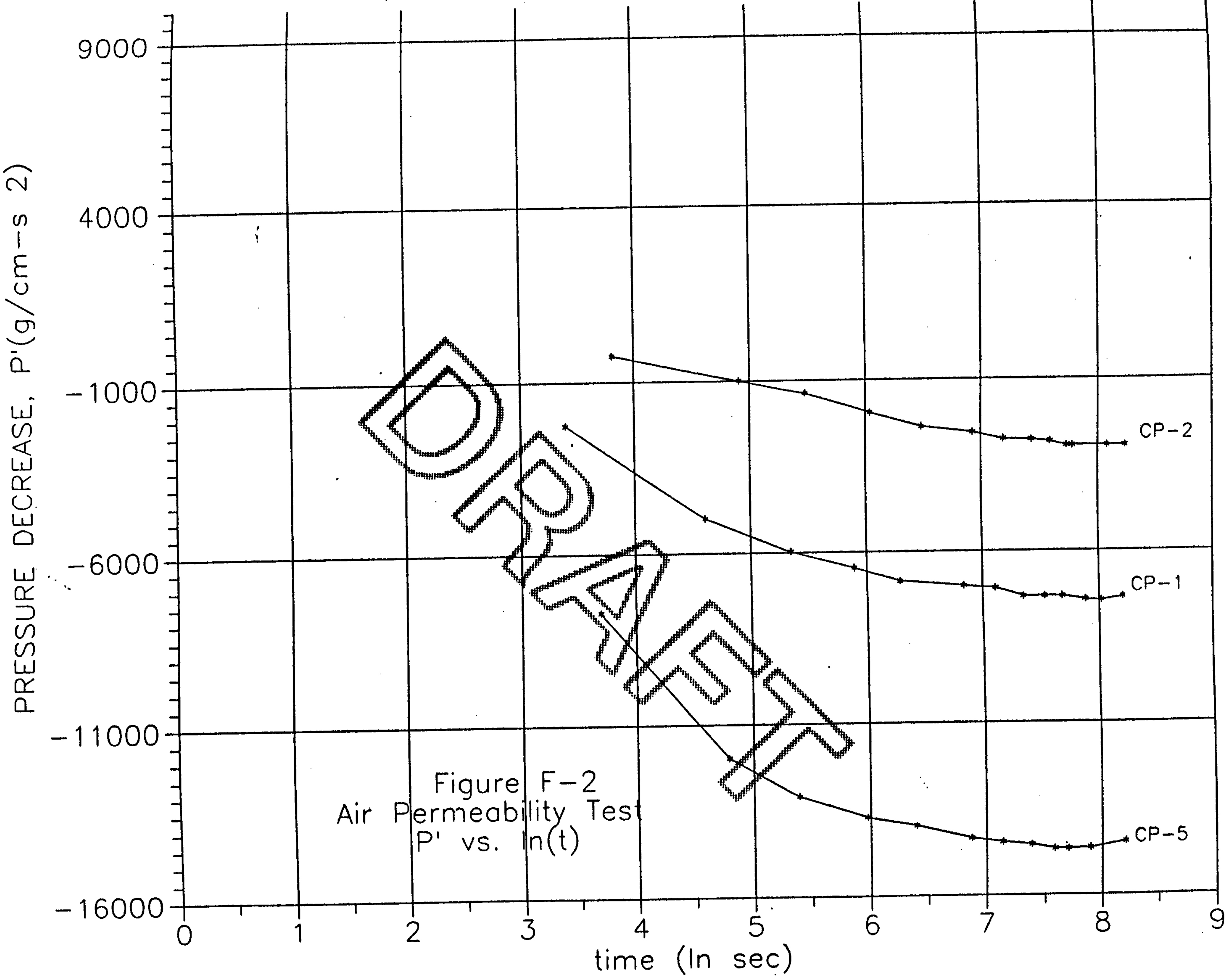


Figure F-2
Air Permeability Test
P' vs. ln(t)

Table F-1
Capehart Gas Station
Air Permeability Test Data

Time (min)	Pressure (in H_20)	ln t (ln sec)	P' $\left(\frac{g}{cm\text{-}sec^2}\right)$
CP-1			
0.50	-0.90	3.40	-2,241.15
1.67	-2.00	4.61	-4,980.33
3.50	-2.40	5.35	-5,976.40
6.00	-2.60	5.89	-6,474.43
9.00	-2.76	6.29	-6,872.86
15.50	-2.82	6.84	-7,022.27
20.50	-2.85	7.11	-7,096.98
26.00	-2.95	7.35	-7,345.99
31.00	-2.95	7.53	-7,345.99
36.00	-2.95	7.68	-7,345.99
44.00	-2.99	7.88	-7,445.60
50.50	-3.00	8.02	-7,470.50
61.00	-2.96	8.21	-7,370.89
CP-2			
0.75	-0.1	3.81	-249.02
2.25	-0.4	4.91	-996.07
4.00	-0.55	5.48	-1,369.59
7.00	-0.78	6.04	-1,942.33
11.00	-0.95	6.49	-2,365.66
17.00	-1.02	6.93	-2,539.97
22.00	-1.1	7.19	-2,739.18
28.00	-1.11	7.43	-2,764.09
33.00	-1.13	7.59	-2,813.89
38.00	-1.18	7.73	-2,938.40
40.00	-1.18	7.78	-2,938.40
54.00	-1.18	8.08	-2,938.40
63.00	-1.18	8.24	-2,938.40
CP-5			
0.67	-3.10	3.69	-7,719.52
2.00	-4.80	4.79	-11,952.80

Table F-1 Capehart Gas Station Air Permeability Test Data			
Time (min)	**Pressure (in H_20)**	**ln t (ln sec)**	p' $\left(\frac{g}{cm\text{-}sec^2}\right)$
3.67	-5.25	5.39	-13,073.38
6.50	-5.50	5.97	-13,695.92
10.00	-5.60	6.40	13,944.94
16.00	-5.75	6.87	14,318.46
21.00	-5.80	7.14	14,442.97
27.00	-5.83	7.39	14,517.67
33.00	-5.88	7.59	14,642.18
37.00	-5.88	7.71	14,642.18
45.00	-5.87	7.90	14,617.28
61.00	-5.80	8.21	-14,442.97

Values of k were determined using each of the three observation wells. The equation variables, A and B, were determined from the plots of p' vs. t in Figure F-2. The equation variables and result of each computation are shown in Table F-2.

Table F-2 Air Permeability Test Equation Inputs and Results					
Observation Well	**r (cm)**	**A** $\left[\frac{g}{cm\text{-}sec^2}\right]$	**B** $\left[\frac{g}{cm\text{-}sec^2}\right]$	**k [cm^2]**	**k [darcys]**
CP-1	534	-1,953	4,297	3.9×10^{-7}	73
CP-2	1,500	-671	2,301	8.1×10^{-7}	152
CP-5	277	-3,233	4,043	2.4×10^{-7}	46
Notes: Extraction well was CP-4. $\theta_a = 0.26$. 1 darcy = 9.8697×10^{-9} cm^2.					

The geometric mean of these permeability estimates was calculated. The result (80 darcies) is consistent with the silty sand materials found beneath the surface at the site (Freeze and Cherry, 1979).

Values for air permeability were also estimated using distance-drawdown relationships. For this calculation, the airflow rate and the thickness of the flow zone had to be estimated. The airflow was estimated to be 20 cfm, and the flow zone thickness was assumed to be 15 feet, or slightly greater than the 12-foot-long filter packed interval at Well CP-4. The equation used to estimate the permeability is:

$$k = \frac{2.3\,Q}{4\pi\,\Delta h}\,\frac{1}{b}\,\frac{\mu}{\rho g}$$

where:

Q	=	estimated flow rate [cm^3/sec]
Δh	=	change in drawdown in cm gas over one log cycle of distance
b	=	flow zone thickness [cm]
ρ	=	density of air [1.3×10^{-3} $\frac{g}{cm^3}$]
g	=	gravitational constant [980 cm/sec^2]

The remaining variables are the same as defined above. Figure F-3 shows the distance drawdown data. Data from Observation Wells CP-1, CP-2, and CP-5 were used to estimate the Δh value. The presence of significantly greater drawdown than extrapolation of data from these wells would predict at the pumping well (CP-4), suggests that the efficiency of the pumping well was low.

Carrying out the calculation of k with a Δh value of 7,718 cm gas leads to an estimated permeability value of 1.4×10^{-7} cm^2, or 14 darcies. This value is in reasonable agreement with the geometric mean k of 80 darcies estimated using the time drawdown relationships.

Radius of Influence

The radius of influence (ROI) was estimated by extraploation of the semilog plot of negative pressure in the observation wells as a function of radial distance from the extraction well. The extraction well vacuum pressure was measured at -3.25 inches of mercury (-43.80 inches of water). The extraction flow rate was estimated at approximately 20 standard cubic feet per minute (scfm). Steady-state negative pressures were measured in Observation Wells CP-1, CP-2, and CP-5 at -3.00, -1.18, and -5.88 inches

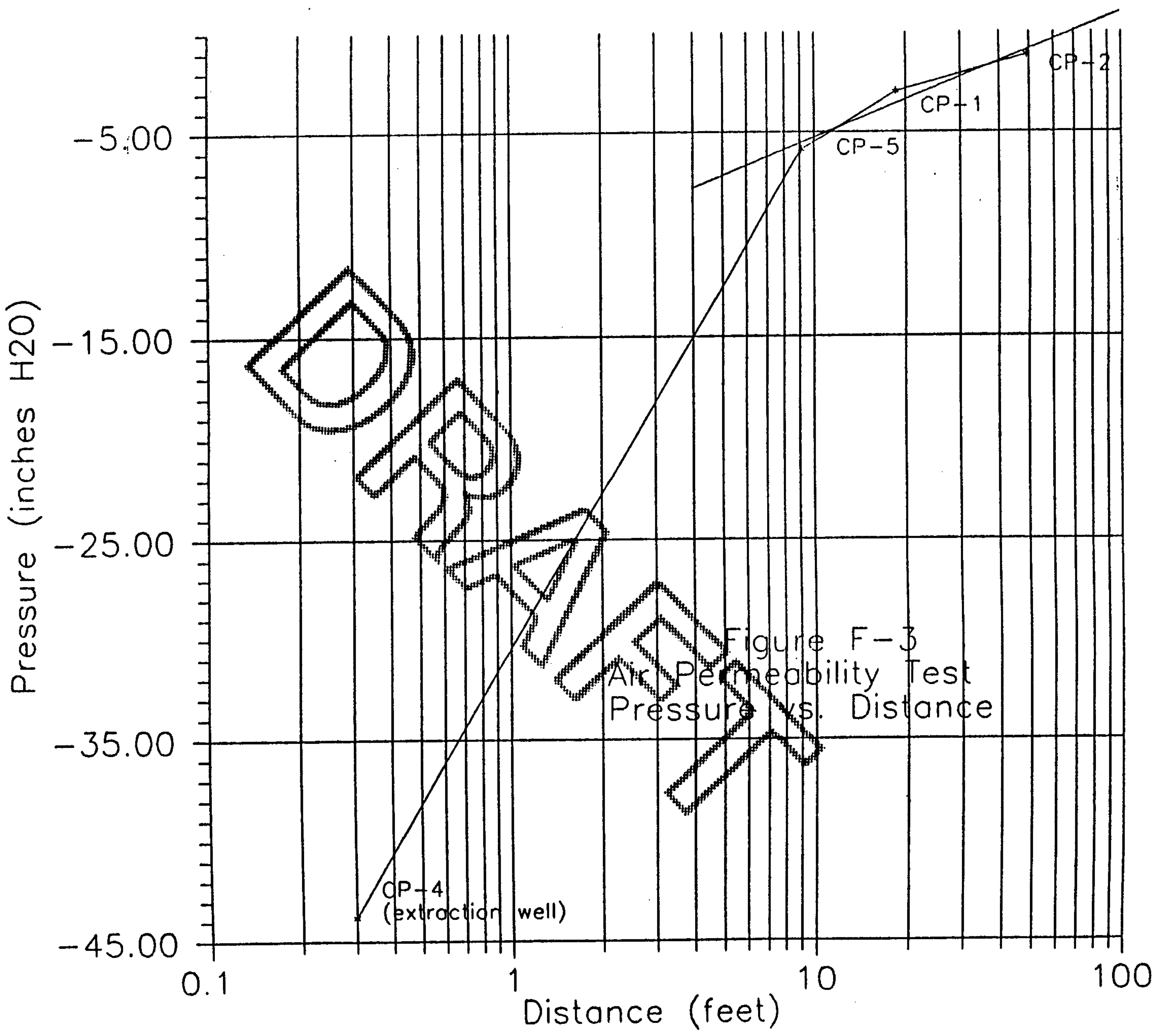


Figure F-3
Air Permeability Test
Pressure vs. Distance

of water, respectively. Based on the semilog plot of pressure versus distance, the apparent ROI for CP-4 was approximately 70 feet.